MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA

VOLUME 97

GEOLOGY AND MINERAL RESOURCES OF WEST BENGAL

BY

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LIST OF PLATES

GEOLOGY AND MINERAL RESOURCES OF WEST BENGAL

PART I

CHAPTER I

INTRODUCTION

The present publication is based on an unpublished report entitled, "Geology and Mineral Resources of West Bengal", prepared during 1952, by A. Hunday, previously of the Geological Survey of India, which has now been thoroughly revised and brought up-to-date by S. Banerjee of the Geological Survey of India. This volume will meet the long-felt need for a comprehensive and authoritative monograph on the subject.

A. Hunday was guided in this work by late Dr. P. K. Ghosh, the then Superintending Geologist in-Charge of the Eastern Circle, Geological Survey of India, during 1952. Subsequently in 1954, he prepared a note entitled, "Mineral Resources of West Bengal" based mainly on the above report, at the instance of the West Bengal Government in connection with their proposed publication on the resources of West Bengal. As the publication of this report did not materialise at that time, it had to be necessarily revised taking into account the data of later years, when it was decided to publish it. At the instance of the Director General, Geological Survey of India, S. Banerjee of the Geological Survey of India undertook the work of revising and bringing up-to-date the above note of A. Hunday in the beginning of 1962.

This publication is based mainly on the work of the officers of the Geological Survey of India.

The potentialities of the State are restricted to the western belt in respect of the metallic and non-metallic minerals while the eastern belt, since found to contain concealed Tertiary formations under alluvium, is being actively explored for mineral oil and natural gas.

In respect of the mineral industry, the growth during recent years has been rapid indeed, with almost a three fold increase in the value of mineral production in 1962 (Rs. 406 millions) when compared with that in 1951 (Rs. 143 millions). Nevertheless, this growth as in the past decades, was, as usual, contributed almost wholly (99 per cent.) by coal, which showed a spectacular rise in

production coupled with the increase in the price. Other minerals, such as clay, salt and limestone, tungsten-ores, manganese-ores, mica etc. contributed only to a minor share in the growth of the mineral industry in the State. This confirms that the pattern of growth of the mineral industry remained the same and continued to be centred around coal.

Acknowledgements

Dr. P. K. Ghosh, the then Superintending Geologist, Geological Survey of India, kindly initiated A. Hunday for the preparation of a report on the "Geology and Mineral Resources of West Bengal" in 1952.

The authors are thankful to some of their colleagues, particularly to Shri G. N. Dutt, Superintending Geologist, Geological Survey of India, for his valuable suggestions given while preparing the first account itself in 1952.

The authors are grateful to Dr. B. C. Roy, Director General, Geological Survey of India, for his kind permission to publish this report after being revised in the light of later data.

The authors also wish to thank Dr. S. V. P. Iyengar, Superintending Geologist, Geological Survey of India, for his interest in the work, to the Director, and the Mineral Economist, Indian Bureau of Mines, for providing the senior author with the latest mineral statistics pertaining to West Bengal, to Shri V. V. S. R. Hanumantha Rao, I. B. M., for suggestions and to Shri A. S. Akolkar, I. B. M., for assistance.

In respect of investments and survey of the industries etc., the various vital and relevant informations were collected from the "Techno-Economic Survey of West Bengal", published by the National Council of Applied and Economic Research, New Delhi.

Similarly, in respect of mineral statistics, utilisation etc., much of the useful data were collected from the "Mineral Year Book" published annually by the Indian Bureau of Mines.

While every attempt was made to incorporate and acknowledge the work and findings of various workers in the State, it is by no means claimed that the incorporation is exhaustive. For any omission and commission which might have inadvertently appeared, the authors express their sincere regrets.

Area

The State of West Bengal came into existence on the 15th August 1947, with the historic partition of India and the consequent birth of Pakistan. As a result of this partition, the new State of West Bengal, which was carved out of the old Bengal, could only have 40 per cent. of the original area, the rest merged with East Pakistan.

The State underwent significant changes in her political boundary since then. From its original two isolated portions in the north and south wedged by East Pakistan, which covered an area of 76,343 sq. km., (29, 476 sq. miles), it could thus emerge as a large continuous tract through the 'State's Reorganisation Act' with the accession of territories covering 11,351 sq. km. (4,452 sq. miles), in three successive stages.

On the 1st January 1950, the former Princely State of Cooch Behar merged with West Bengal while Chandannagar was added to this State on the 2nd October 1954. Subsequently, after the State's Reorganisation Act in 1956, this State could get some additional territories as well as the vital link (through her own territory) between the hitherto isolated blocks to the north and south. These territories, which were acceeded to West Bengal, include a considerable portion of Purulia sub-division of the Manbhum district and a portion of the Kishanganj sub-division of the Purnea district, previously belonging to the Bihar State.

Thus, the present State of West Bengal covers an area of 87,616 sq. km. (33,829 sq. miles) within Lat. 21°10′ and 27°38′ N. and Long. 85°50′ and 89°50′E., which works out to roughly three per cent. of the area of India's land surface.

As per 1961 census, the State has a population of 34.9 million (eight per cent. of the all-India population), which works out to a density of population of 398 per sq. km. (1,032 per sq. mile, second highest in India).

The State is comprised of 16 districts included in two Divisions of Presidency and Burdwan. Of these, the Presidency Division contains the following nine districts (with the district headquarters indicated in brackets), *viz.*, Calcutta (Calcutta), 24 Parganas (Alipore), Nadia (Krishnanagar), Murshidabad (Berhampore), Malda (English Bazar), West Dinajpur (Balurghat), Jalpaiguri (Jalpaiguri), Cooch Behar (Cooch Behar) and Darjeeling (Darjeeling); while the Burdwan Division includes seven districts *viz*, Burdwan (Burdwan), Midnapur (Midnapur), Bankura (Bankura), Birbhum (Suri),

Hooghly (Chinsura), Howrah (Howrah) and Purulia (Purulia).

Calcutta is the capital of the State, while Darjeeling is the summer capital.

The State of West Bengal has land frontiers on its three sides, being bordered by seven States and the southern frontier is limited by the sea, the Bay of Bengal. The States of Assam and East Pakistan lie to the east of West Bengal, while Sikkim and Bhutan to the north and north-east, Bihar and Nepal to the west and north-west and Orissa to its south-west.

Transport and Communication

Roadways.—By the end of 1956, there were 22,663 km. (14,082 miles) of major roads excluding village roads in West Bengal and 1,127 km. (700 miles) of National Highways within the State. The National Highways and major roads of the State include the Grand Trunk Road (Calcutta-Delhi-Peshawar), Calcutta-Bombay, Calcutta-Madras, Birbhum-Assam National Highways, Calcutta-Siliguri, Siliguri-Gangtok, Calcutta-Bongaon State Highways, besides major trunk road, Jessore road, Barrackpur Trunk Road, Bankura-Midnapur Trunk Road etc. The Second Plan had a provision for the construction of 5,794 km. (3,600 miles) road, and a further increase in the roadways is anticipated in future. This should be economically possible particularly in its western and northern districts where road metals are plentiful. During 1961-71, an investment of Rs. 370 millions is envisaged for road development.

Railways.—The State is served mostly by broad gauge lines of the Eastern and South-Eastern Railways and by the meter gauge line of the North-East Frontier Railways and by narrow gauge lines of the Darjeeling-Himalayan, Ahmadpur-Katwa-Bankura-Damodar River, Burdwan-Katwa, Howrah-Amta, Howrah-Salkia Railways. The total route in kilometres of the railways in West Bengal is reported to be covering 3,364 km. (2,090 miles). The heavy transport of materials for the industry, including coal, is borne by the Eastern and South-Eastern Railways, in the southern plains of this State, which is more industrialised than the northern part. The progress of the Plans marked certain development in the railway system within the State and also in the electrification of a number of lines (Howrah-Burdwan, Sealdah-Ranaghat, Sheoraphuli-Tarakeshwar Section) in the Eastern Railways, which are being extended to Gaya-Mughalsarai, etc. Des-

pite the present development, considerable difficulty and congestion are being experienced in transport of industrial material due to shortage of wagons in particular. The South-Eastern Railways carry a large volume of raw-materials for the Durgapur Steel Plant. It may be interesting to note that in the State of West Bengal, the route mileage of Railways works out to 62.6 miles (100.74 km.), per 1,000 sq. miles (2,590 sq. km.) the highest in the country, and 7.5 miles (12.07 km.) per each 100,000 inhabitants of the population while the corresponding average figure for India is only 27 miles (43.45 km.) per 1,000 sq. miles (2,590 sq. km.), and 8.7 miles (14.00 km.) per each group of 100,000 people. It can be envisaged that towards solving this congestion, further planned development of the railways in relation to the growing industries will be essential, in order to reduce the congestion in transport.

The State has considerable reserves of railway ballasts particularly in the western and northern districts, which would be useful in course of further development of the rail links within the State.

An investment of Rs. 540 millions is envisaged for the development of the Railways within the State during 1961-71.

Waterways.—It is reported that the State has over 2,672 km. (1,660 miles) of inland waterways including 2,404 km. (1,494 miles) in navigable rivers and 267 km. (166 miles) through canals. The steamer services on the Rupnarayan and Hooghly rivers provide additional facilities in respect of internal trade and communication within the State. Besides, ferry services ply across many of the larger rivers of the State during and shortly after the monsoons.

An investment of Rs. 50 millions is envisaged towards the development of waterways within the State, during the Third Five Year Plan.

Airways.—Modern facilities of quick transport by civil airways exist in the State. Among the airfields Dum Dum, near Calcutta, ranks first not only in the State, but is considered to be one of the busiest and biggest in the east. This airfield provides an international link through the services of the Indian Airlines Corporation, Air India International and also through many other international airways.

Apart from the international link provided by Dum Dum, the State has a local airways system within its limits, linking its southern part with the northern, *i. e.*, Dum Dum-Bagdogra (located near Siliguri in the Darjeeling district) covering about 449 statutory kilometres.

An investment of Rs. 3,000 millions is proposed for the development of transport and equipments in the State during 1961-71, which is estimated to yield a projected income of Rs. 750 millions during the same period.

Climate and Rainfall.—The climate of this State is tropical in the plains and semi-Alpine in the Himalayan region. In winter, the temperature falls below freezing point in the Himalayan region while it rises to over 26.7°C. in summer. In the plains, the summer temperature ranges between 27.7°C. and 43.3°C. A higher range is generally felt in the western districts. It is reported that the maximum and the minimum mean temperatures are 8.3°C. and 1.7°C. respectively in Darjeeling while they are 23.3°C. and 10°C. in the Jalpaiguri district. Winter climate during the months from November to February is enjoyable, particularly in the plains of the State. Similarly, summer is pleasant in the hill terrain of the northern region.

Rainfall.—The rainy season starts generally in June and continues till September in the plains, while in the Himalayan region it starts a little earlier. There is a wide variation in the rainfall (ranging from 112.5 to 175 cm.) in different parts of this State. The heaviest rainfall is recorded in the Himalayan districts, ranging from 250 to 500 cm., while the districts located in the plains receive rainfall ranging from 125 to 187.5 cm., the lowest rainfall being recorded in the Bankura district.

Wide variations in the intensity of rainfall and also in the topographical elevations between the different parts of the State, naturally result in occasional floods (common in the alluvial plains), but more often, the State as a whole suffers in respect of scarcity of water supply due to droughts. Due to the beneficial effects of floods, the affected areas are rejuvenated in respect of their agricultural potentiality through fresh deposition of silt.

The rainfall in the different parts of the State is given below :—

Name	(in cm.)
The plains of Darjeeling, Jalpaiguri and Cooch Behar districts	300-400
West Dinajpur	200-300
North Malda	160-200
South Malda	140-160

Name	(in cm.)
Murshidabad	140
Nadia	140-160
24-Parganas including coastal area	160-200
Howrah and Hooghly	140-160
Western Bankura and Burdwan	120-140
Eastern Bankura and Burdwan	140-160
Midnapur district excepting the coastal belt	140-160
Coastal area	200

Forests, jungles, swamps, etc.

Only about 14 per cent. of the State is covered by forests. These are unevenly distributed and are located mainly in the northern part of the State comprising the coniferous, deciduous and evergreen forests in the sub-Himalayan regions of Darjeeling and Jalpaiguri districts, and in the Sunderbans located in the southern part of 24-Parganas district ; and the deciduous forests of the western districts and mangrove forests at the Bay mouth.

These are large areas covered by scrubs of thin jungle of *Sal* (*Shorea robusta*) and *Palas* (*Butefrandosa*) trees in the uplands to the west.

The forest cover extends over an area of 12,111 sq. km. which works out as 0.045 hectare *per capita* in the State *vis-a-vis* 0.2 hectare for India.

It is worth noting that six districts of the State located mainly to the east do not have any forest cover.

The important types of vegetation in the forests of the State are reported to include the following : *Shorea robusta, Tectona grandis, Michelia champaca, Schima walliohi, Chukrasia tabularis, Betula* sp., *Abies, Densa,* Oaks, *Pinus roxburghii, Dalbergia sisso, Acacia catechu and Salmalia malabarica.*

The modest forest resources have potentialities for planned development and utilisation to the best interest of the State.

The projected income from forest resources in the State during 1960-61 was Rs. 11 millions. It is further estimated that with the proposed investment of Rs. 61 millions for the development of forest resources during 1961-71, the projected income from the forests will increase to a total of Rs. 26 millions (including an additional income of Rs. 15 millions, registering an increase of

136.36 per cent. in the total income). The rate of growth of the forest output is estimated by National Council of Applied and Economic Research to be two per cent. higher than the output in the Second Plan.

In the coastal area of the Sundarbans, there are extensive swamps locally known as *bil* and shallow saltpools, lakes and small islands. Among these islands, the names of Sagar and Dalhousie may be mentioned.

Drainage

This State is drained by a number of allogenic rivers and streams. The Ganga (known as Bhagirathi in the upper and Hooghly in its lower reaches) is the principal river in the vast alluvial stretches to the south, while the Tista forms the main drainage in the north.

In the southern plains, the Ganga enters West Bengal near Malda and as the Bhagirathi and Padma near Chapghati. The chief tributary of the Bhagirathi is Damodar, while others worth mentioning are the Jalangi, More (Mayurakshi), Kansabati, Mahananda, Dwarakeswar (known in the lower reaches as Rupnarayan), Ajoy, Mechhi, Gangadhar, Punarbhaba, Silai, Gandheswari, Atrat, Kalindi, Jamuna, Bidyadhari, Matla, Ichamati, Raimangal, Baramahano and Goashaba. The Bhagirathi is, in fact, a distributary of the Ganga. Calcutta, the capital of the State is located on this river which provides this port with a vital link with the sea.

The navigational safety of this river, which plays a vital role in moulding the destiny and industrial development of the State, needs to be essentially ensured through appropriate measures in preventing silting. In this connection, the Ganga Barrage (Rs. 685.9 millions) project is proposed. This envisages :—

(i) a barrage across the Ganga at Farakka ;

(ii) a barrage across the Bhagirathi at Jangipur above the outfall of the canal ;

(iii) a feeder canal (42.4 km. long) upstream of the Ganga barrage, on the right bank and outfalling into the Bhagirathi, downstream of the Jangipur barrage.

The south-western corner of the State is drained by the Subernarekha river, which falls into the Bay of Bengal near the mouth of the Hooghly. The principal river as well as the tributaries of the plains have in common, easterly and south-easterly trends.

In addition to these, there are numerous *nalas* and *nadis* intersecting the plains of the State. These rivers and their larger tributaries are perennial, while the smaller rivulets or streams remain generally dry during the summer or retain small pools of water near the bends.

The fluctuations in the water-level are observed in different seasons in the streams; they have low water-levels before the rains and larger flow in the wet season. The discharge of the Ganga near the Hardinge Bridge on the 28th August 1942, was 42,855 cu. m. per second and that on the 9th June of the same year was 14,154 cu. m. per second.

In contrast with the rivers in the southern part of the State which have generally a low gradient, a sudden rise (0.5 to 1 m. in a day) in the water-level followed by a quick subsidence is commonly noticed in the hill streams of the northern part of the State.

In the northern part of the State, apart from the Tista river, the names of Jaldhaka-Dharla, Torsa-Raidak, Sankosh-Gangadhar, and Rangit rivers which are the tributaries of Brahmaputra, may also be mentioned.

The records of flow of some of the important rivers in the southern plains are—the Damodar has a flow of 3.54 cu. m. per second in March in contrast with 3,735 cu. m. per second in September; while the Ajoy, which retains small pools of water at places in May, has a flow of 340 cu. m. per second in August; the Rupnarayan and Kasai record a flow each of 0.2 cu.m. per second in February, and the Subernarekha, a flow of 10 cu.m. per second in April. The last three rivers retain only very small pools of water during the summer months.

Practically, all the rivers in the south in their lower reaches, have a rather sluggish flow along their meandering courses during the greater part of the year over fairly wide sand beds.

The rivers in the southern plains of the State are usually liable to devastating floods during monsoon. However, many of them such as the Damodar, More (Mayurakshi) and Kansabati have since been tamed through construction of dams and barrages. They are also sources of hydel power besides having an extension of the irrigational facilities through the chain of canal system. The Subernarekha river which flows to the south-west of the Midnapur district, if properly

canalised, linking the mineral-rich regions to the west, of the State, can provide economic transport facilities for such important raw materials like coal from Bokaro and iron-ores from Mayurbhanj for a steel mill besides catering many other industries such as those for fertiliser and cement near Contai (located within a short distance from the Haldia port).

The rivers in the north are also subjected to frequent floods during the rains, causing great damages. But many of them can be sources of hydel power.

It will be of interest to note that in recent times, there had been some marked changes in the courses of some of the rivers. The Ganga or Bhagirathi appears to have shifted eastward . Before 1787, the Tista used to flow into the Ganga through the Atrat channel, and its water used to be distributed through the Karatoya and Punarbhaba. Now, it is discharging into the Brahmaputra. Since its diversion, many of the rivers in North Bengal have been deprived of their head-waters, resulting in their dessication.

The diversion of the Brahmaputra from east of Dacca and Madhupur jungle to the west of the plain occurred only a century ago. The diverted portion which broke away from the mother channel to join the Ganga forms the river Jamuna.

The detalic portion of southern Bengal was formed at a geologically late period, at the mouths of the Ganga and the Brahmaputra. According to J. Ferrgusson, about 5,000 years ago, the sea washed the Rajmahal hills and the country around Sylhet (now in East Pakistan) as well as a part of Bengal which was under the lagoon of that sea.

In contrast to the eastern portion of the Ganga delta which is changing at a rapid rate giving rise to new ground and terrain, the configuration of the western portion remained practically unchanged.

The continental shelf in the Bay of Bengal has a width of 112 km. near the Midnapur coast which is bounded by the 250- fathom contour.

There is a sub-marine canyon (1,000 fathom deep) south of Harinbhaga (now in East Pakistan) estuaries. The Midnapur coast-line is smooth, having one of the finest sea beaches at Digha. In the Sunderban area, however, the coast-line is broken with a number of estuaries, each simulating an arm of the sea. West of Haringhata, these are kept open by tidal water and local rains. The tidal bores are

stronger in the western area carrying the suspended materials far inland for subsequent deposition, particularly on the bed of the estuaries and in adjacent flood basins, with consequent rise in their level.

Soils

The State of West Bengal is dominantly covered by alluvial soil in over 75 per cent. of its land surface in relation to the disposition of the geological formations and the geomorphological background. The rocky uplands lie mostly in the western districts and also in portions of northern districts constituting hardly 25 per cent. of the area. These uplands contain exposures of various geological formations, older than the alluvium and are either bare or covered by thin mantle of soil, rarely exceeding a few metres in thickness.

The residual soils of this part of the terrain develop by weathering of the different rock types and are named as granitic-, micaceous-, and lateritic-soils after the names of the parent rocks.

Four major categories of soil are recognised in the State. These are alluvial, lateritic, podzolic (mostly found in the valleys and depressions in the Darjeeling Himalayas on the gneisses and schists) and mangrove soils.

Towards the east, these residual soils merge into the alluvial soil, which attains an enormous thickness in the low level plains to the east.

On textural basis, these alluvial soils have been grouped into sand, sandy loam, river silt or silt loam, clay loam, clay, saline soil and red earth. Of these, clay loams are recognised to be dominant in the plains of Bengal. In respect of the distribution of the other types, it may be mentioned that coastal sand dunes are formed by pure sand; along the northern bank of the Ganga are found the loamy sands while the alluvial plains in the north contain sandy loams and the banks of the Tista and Brahmaputra rivers are formed by silts. The regions of swamps and alluvial lakes contain clays, while the hill-wash along the foot of the Darjeeling Himalaya include gravels and coarse sands of the alluvial fans (piedmont deposits). The coastal area in the Sunderban contains saline soils with white efflorescence of sodium chloride and other soils, impregnated by tidal currents in the estuaries.

Soil erosion is comparatively more active in the upland tracts to the west and also to the north. The fertility of these soils for agricultural purposes varies a great deal in different

regions in relation to the types. It is recorded that soils, in general, all over the State are deficient in nitrogen, organic matter and lime.

The podzolic soils in the hilly areas are found to be suitable for the cultivation of tea. The lateritic soil can be suitably irrigated to yield a good crop. The alluvial soil contains a superior fertility for growing a wide range of crops.

The mangrove saline soil found in the estuaries of the 24-Paraganas district, are covered by mangrove, forests and is hardly of much use for other types of cultivation.

Power

Industrial development of the State is vitally linked with availability of power. The chief source will naturally be the thermal energy produced from the vast potential coal resources of the State, supplemented by hydel power through river valley projects, particularly in the southern regions. The northern districts will have to depend largely on hydel power.

During 1957-58 the State with a consumption of 66 kW *per capita* of of electrical energy ranked highest compared to an all-India *per capita* consumption of 24 kW. All the same, this is concentrated in Calcutta and its suburbs only, while the deficiency of power is felt acutely in other regions.

During 1957-58, 1,880 million kW of power was consumed including 15 per cent. for domestic and 75 per cent. for industrial development.

The Jaldhaka hydel project, Durgapur (75 mW) and Bandel thermal power stations (300 mW) and the D. V. C. grids, Calcutta Electric Supply Extension scheme (500 mW) etc. mark a significant development in respect of power supply, particularly to the industries. According to the National Council of Applied and Economic Research, the power required by the State by the end of the Third and Fourth Five-year Plans is 1,500 mW and 2,500 mW respectively, *vis-a-vis* the present availability of about 900 mW. In this regard, the following suggestions have been made :—

(i) The Tista and Jaldhaka rivers have potentials of supplying hydel power to the extent of 1,000 mW and 77 mW respectively which need attention for full-scale development. This would meet the requirement of the northern districts.

(ii) Super thermal power station (500 mW to be increased to 1,000 mW in the Fourth Plan), to be set up in the coalfield region utilising the vast resources of suitable coal, and the capacity of the Durgapur thermal power station to be increased.

The cheap and adequate power should be made available to the existing heavy metal-based industries to promote further growth.

(iii) Possibility of construction of an extra high tension transmission line for the hydel site in North Bengal to pass through West Dinajpur and Malda and to join the D. V. C. grid at or near Burdwan.

During the Third Plan, Rs. 1,200 millions (Rs. 200 millions for northern districts and Rs. 1,000 millions for the rest) and Rs. 2,000 millions during the Fourth Plan are estimated to be the investment requirements for development of power in the State.

Multi-purpose Projects

While attempting to assess the mineral resources of this State, characteristically a land of flowing rivers, proper emphasis should be laid on such natural assets as the reservoir of underground water, the noble rivers and the vast stretches of alluvial plains. These natural assets are of great value and are ancillary in various ways to the development of mineral industry. The full potential of the predominantly great fertile plains making up around 80 per cent. of the State and of the underground water resources have not yet been realised. However, a beginning towards the utilisation of these vast potential natural assets has been made in recent years by effecting implementation of the multi-purpose river projects and by a systematic study of the underground water resources for using the underground water for large-scale irrigation.

The multi-purpose river projects now under implementation in West Bengal include the Mayurakshi Reservoir Project in the Birbhum district and the Durgapur barrage on the Damodar river on the borders of Bankura and Burdwan districts.

Mayurakshi Project.—The Mayurakshi or More is a hill stream, the source of the river being in the uplands of the Santhal Parganas in Bihar. After flowing for about 240 km. from its source, the river flows into the Bhagirathi near Dutwabati.

During the latter part of its course, it traverses through the undulating plains of the districts of Birbhum and Murshidabad in West Bengal. The principal streams running almost parallel to the Mayurakshi are the Brahmani, Dwarka, Bakreswar and Kopai which also have their sources in the hills of the Santhal Parganas. At a distance of about 97 km. from the source of Mayurakshi where it passes through a gorge, a dam known as Messanjore dam, has been constructed across the river. Besides this dam, the construction of a barrage known as the Tilpara barrage, across the Mayurakshi and located 32 km. below the dam, has recently been completed. The Messanjore dam is located at a distance of about 20 km. from the district headquarters of Santhal Paraganas in Bihar, while the Tilpara barrage is about three kilometres from Suri, the district headquarters of Birbhum in West Bengal.

The Messanjore dam (now named Canada dam) is about 660 m. long out of which about 225 m. will be controlled by 21 radial gates (each 9.1 m. long and 4.6 m. high), and contains a roadway on the top. Its maximum height is about 45 m. from the deepest foundation and about 35 m. above the bed-level of the rivers.

The length of the Tilpara barrage is about 310 m. It has mild steel gates and has two main canals on either bank of the river. This barrage is expected to hold up the water upto a height of six metres and create a reservoir eight kilometres long in the river bed. Each of the main canals has a length of 118 km. and has a capacity of 99 cu. m per sec. equivalent to 5.9 million litres of water per minute. The main canals will be taken over a number of cross-drainage works. The total length of the canal system including the distributaries will be about 1,352 km. There will be about 1,700 km. of canals in the entire system and nearly 1,200 various canal structures will spread over an area of 3,470 sq. km. The barrages across the Bakreswar and the Kopai on the south bank and the Dwarka and Brahmani on the north varying in length between 61 m. and 137 m. are the most important ones. The total estimated cost of the barrage of Mayurakshi is about Rs. 12.2 millions.

This Rs. 150-million Mayurakshi (or More) Project by the State of West Bengal aims to irrigate 240,000 hectares of land during June to October and 48,500 hectares during November to May in the districts of Birbhum, Murshidabad and Burdwan in West Bengal and 12,104

hectares during June to October in the district of Santhal Parganas in Bihar, and shall produce an increased yield of 31 million tonnes of paddy (i. e. above half a tonne per acre) and about 30,500 tonnes of *Rabi* crops besides producing 4,000 kW. of hydro-electric power for the development of industries.

The first set generating 2,000 kW. was commissioned in December 1956 and February 1957.

The project for the preservation of the Calcutta Port at an investment of Rs. 685.9 millions is to be completed in eight years through the construction of Farakka barrage across the Ganga, Jangipur barrage across the Bhagirathi and of a 43 km. feeder canal.

The D. V. C. Canal was completed in 1953 at a cost of Rs. 13 millions and the area under irrigation comes to 260,000 hectares.

CHAPTER II

PHYSIOGRAPHY AND GEOMORPHOLOGICAL HISTORY

Physiography.—The State of West Bengal is broadly divisible into three well marked physiographic regions, including (i) Darjeeling Himalaya in the north, (ii) the undulating rocky plateau land in the west and (iii) the vast stretch of the low-lying plains and the deltaic regions in the east.

The major portion of the northern districts, *viz.*, Darjeeling and Jalpaiguri, is located on the Himalayan range, which in sharp contrast overlooks the plains of Bengal to the south. In the lower reaches, the elevations are hardly 300 m. while the highest elevation seen within the border of the State, is around 3,658 m. above m. s. l., near Sandakphu to the north-west. Apart from Darjeeling (2,134 m. above m. s. l.), there are other well known hill resorts such as at Kurseong and Kalimpong (1,524 m. above m. s. l.) in the lower altitudes. Of the numerous hill peaks, the names of Ghum (2,398 m.) and Tiger Hill (2,615 m.) located near Darjeeling, may be mentioned.

In contrast to the Himalayas, the western plateau land comprising a major portion of the western districts of the State, *e. g.* Purulia, Bankura, Birbhum, Burdwan, Midnapur and Murshidabad contains only a few isolated peaks (ranging from 290 to 643 m.) and in general, forms the undulating plains in continuity with the Chota Nagpur plateau to the west and gradually merging in to the alluvial plains in the east. Portions of low Rajmahal hills are included in the Birbhum and Murshidabad districts. To the east and occupying a dominant portion of the State are the monotonous, flat alluvial plains of Bengal, which are barely a few metres above the mean sea level. The older deltaic and flood plains lie to the north of Ganga-Padma axis while the younger deltaic flood plains lie to the south of it, and the erosional flood plains stretch to the west of Bhagirathi-Hooghly river. The general slope of these is to the south-east, south and east respectively. The stretch of the plains occupied by the youngest alluvium is an extremely low-lying flood plain with a web of distributaries.

Calcutta is only at an elevation of 7.6 m. above the mean sea level. The surface in the plains around Calcutta is studded by a number of depressions, locally known as *bils* which are covered by salt water at places (as in the tidal salt lakes near Calcutta).

The plains lying west of the Bhagirathi river have steep slopes and contain a number of terraces. These flats grade into the rocky undulating Archaean terrain to the west. The typical piedmont plain of the Terai and western Duars lies at the foot of the Himalayas.

Geomorphology.—The sharp contrast in the variation of topographical features within the limits of the State is remarkable. The eastern low lands, which are only a few metres above the sea level, rise gradually to the rocky undulating elevations to the west. The most conspicuous among the isolated relict hillocks of these uneven westerly tracts are the Panchet (643 m.), the Biharinath hill (452 m.) composed of Panchet and supra-Panchet sandstones, the Susunia hill (442 m.) made up of felspathic quartzite of (?) Purana age and the Gorangi (291 m.) and Baghmundi hills (677 m.).

A considerable region of the western part of the State (comprising an area of 3,100 sq. km.) is covered by the Archaeans which form the eastward extensions of the Peninsular shield. These regions were subjected to great diastrophic movements and erosion through a considerable period. On the deeply denuded edges of the contorted Archaeans, the sedimentary formations of Purana age were deposited. Only a few isolated possible representatives of the Purana are noted in the State.

The post-Purana period witnessed large-scale crustal movements and deformation (Hercynian or Variscan) that brought about revolutionary changes in the physiography of India and affected the State of West Bengal as well. Consequent to the readjustment that followed these crustal movements, large areas of India, hitherto land masses, were brought under sedimentation. During this period of the earth's history, the great Tethys or the ancient Mediterranean Ocean encircled almost the whole of the earth and covered immense tracts of India which are now the site of the northern zone of the Himalayas. In the geosynclinal trough, which was then forming at the floor of the Tethys, considerable thickness of marine sediments ranging in age

from Permian to Eocene were deposited. These post Purana-Upper Carboniferous crustal movements manifested themselves into block type of earth movements in the Peninsular India and were responsible for development of tensional cracks and subsidence of large linear tracts between more or less vertical fissures culminating into basin-shaped depressions or troughs on the ancient Archaeans.

Thus, the commencement of the Aryan era was followed by a cycle of fluviatile sedimentation resulting in the subsidence of the loaded basins. This process which later continued *pari passu* beginning with the Upper Carboniferous of the Palaeozoic till the end of the Mesozoic period (with certain stratigraphic breaks or unconformities as in the middle Trias) resulted in the formation of the most characteristic system of thick fluvialile or lacustrine formation of shales and sandstones with intercalations of valuable coal seams belonging to the Gondwana system. Deposition of these immense formations with their valuable coal seams in the gradually sinking basins are responsible for their preservation not only from denudation but also from the effects of folding and crushing.

This Gondwana period witnessed a cycle of climatic changes as evinced from the nature of its rock formations and their fossil content. The presence of glacial boulder beds in the same horizon in widely separated areas at the base of the Gondwanas suggests the prevalence of glacial epoch at the commencement of the Upper Carboniferous period. This cold cycle, which recurred during the deposition of the Panchet rocks (revealed by the presence of undecomposed felspar grains) was intervened by a warm climate during the Damuda period which marked by the preponderance of coal seams pointing to the abundance of terrestrial vegetation at that time. The second cold climate during the Panchet times was later followed by the overlying thick red sandstone containing much ferruginous matter, and by almost total absence of vegetation.

During the Upper Gondwana period, the Gondwanaland was subjected to marked vulcanicity, which manifested itself into outpouring of Rajmahal lava flows and instrusions of numerous sills and dykes of basic and ultrabasic rocks *e.g.* dolerites and lamprophyres. These intrusives are abundant in the Lower Gondwana rocks, found in the State, and have often damaged the coal seams near their contacts (Banerjee, 1953).

The end of the Mesozoic and the commencement of the Tertiary era witnessed tremendous physio-geographic vulcanism and conspicuous revolution in the distribution of land and sea. These culminated (1) in the obliteration of the Tethys which was later succeeded by the Tertiary rivers, (2) in gradual uplift of the Tethyan sediments into mighty Himalayan ranges followed by (3) severing of the Indian peninsula from the Indo-African Gondwana continent, and (4) outpouring of vast amount of lava flow known as the Deccan Traps in the Peninsular India.

The uplift of the Himalayas continued by stages throughout the whole of Tertiary period. Four distinct intermittent phases in the upheaval of the Himalayas are recognised which occurred during the (i) the Upper Eocene (ii) Middle Miocene (iii) Upper Pliocene and (iv) later Pliestocene times. Warping of the Quarternary gravel terraces, on either side of Matiali syncline east of the Tista river found by A. Heim and A. Gansser in 1936, is an evidence of late stage uplift in the Himalayas. Observations by Heim show that the Himalayan tectonics are still active as he states that the Daling thrust sheet "has flooded five kilometres towards the plain through 15 kilometres gap in the Siwaliks in the Buxa Duars". The rocks lying on the southern flanks of the Darjeeling Himalayas which are extensions of similar formations of the Peninsular India were also affected and folded during the Himalayan orogenic movements. The Himalayan orogenic belts are characterised by gigantic recumbent folds and overthrusts which brought about complete reversal of the original order of superposition.

Concomitant with the rise of the Himalayas which was followed by the retreat of the Tethyan sea, gradual downwarpping of a parallel belt in the Peninsular tract in front of and parallel to the Himalayas occurred. This was gradually filled up by the alluvial sediments known as the Siwaliks, deposited by the Tertiary rivers. Complex fold movements involved the Siwaliks themselves over which the sediments of the Ganga were unconformably deposited.

Detached occurrences of small fluviatile or estuarine Tertiary gravels and grits, shales and clays are also reported from the north-western corners of the Midnapur district and recently from the Bankura district of the State which may reasonably be expected to extend beneath most of the laterite formations of the above districts. These suggest that whilst depression was going on in the Ganga delta

there was a minor differential upwarp in parts of the State, to the west and south-west of Calcutta.

The Bay of Bengal began to have its present shape from the Upper Jurassic times when it had a gulf extending into Assam and Burma. During the Upper Cretaceous or early Eocene times, the eastern portion of the Bay of Bengal was separated into an Assam gulf and a Burma gulf with the rise of the great north-south oriented Arakan mountains, which continue both to the Upper Assam and into the Andamans, Nicobars, Sumatra, Java etc. The Andaman ridge system is faulted possibly on its both eastern and western sides as suggested by the configuration of the Andaman sea. The faulting down of the Andaman sea took place possibly during the Pliocene times.

In order to explain the origin of the Indo-Gangetic depression, various hypotheses have been advanced by a number of eminent scientists like Eduard Suess, Sir Sydney Burrard etc. Eduard Suess suggested that the movement of Central Asia towards the stable Peninsular India exerted pressure by which the intervening Tethyan geosynclinal sediments were uplifted and thrust against the resistant Peninsular India resulting in the formation of the 'foredeep'. Burrard thought that the plains represent a rift valley bounded by parallel faults on either side. According to the third view, a sag in the crust was formed between the northward drifting Indian continent and Tethyan geosynclinal sediments concurrent with the uplift of the latter into mountain ranges. There are more evidences in favour of the third view.

Later, geodetic observations revealed that the floor of the superficially unbroken 'even stretch' of the Indo-Ganga alluvium is corrugated by inequalities and buried ridges. The belts of high and low densities under the alluvium have their respective names as 'Hidden Range' and 'Hidden Trough' after Burrard. Two such submerged ridges, one between Delhi and Haradwar on the upwarp of the Archaean rocks in structuaral continuation with the Aravalli ; and the other extending from Delhi to the Salt Range with a strike in the N. W.—S. E. direction have been suggested by the data of gravity anomalies. Recent work has also established the existence of another upwarp in the form of a great arc slightly convex to the south between Allahabad and Benaras extending to Shillong, and two minor upwarps, one having strike along north-south through Jalpaiguri (28°32' : 88°44') and the other under the Madhupur

jungle in East Pakistan extending to Garo Hills. Intervening these two minor upwarps, there is a zone of relative depression extending S. S. W. and roughly 80 km. west of Dhulian (24°42' : 87°58'). North of Calcutta, this depression is postulated by Glennie to have changed in direction and has swung round to the south-east parallel to the minor upwarp just to the east of Chittagong. According to Glennie, the Ganga trough does not extend below the delta into the Bay of Bengal. Though locally closed in the Jalpaiguri area, the trough recommences further east and almost certainly bends south following the curve of the Arakan Yoma Range and of the Andaman and Nicobar Islands. The peninsular projection round which the trough bends, shows high postive gravity anomalies, but the great stability of the north-western area is indicated by comparatively small negative anomalies in the trough there. Thus, it appears that there was undoubtedly a land barrier between Calcutta and the ancient Siwalik rivers at the time of deposition of the Siwalik sediments during the Upper Miocene to Pleistocene times, otherwise these instead of flowing into the Arabian sea would have discharged into already existing Bay of Bengal since Upper Jurassic time. The depression of this land barrier which brought about reversal of drainage, must have taken place in the late Pleistocene to Recent times at the dissociation of the Siwalik river or rivers. Recent drilling by Exploratory Tubewells Organisation confirmed the existence of a buried ridge to north of the Bengal basin aligned east-west between the Rajmahal and Garo hills. Granite gneiss and granite were touched at depths of 260.6 m. and 307.2 m. at Mandilpur (25°04' : 88°07') in Maldah district and Buniadpur (25°23' : 88°23') in the West Dinajpur district (Banerjee, 1963). Further fossiliferous strata of late Cretaceous to Tertiary age comprising shales, sandstones of marine, estuarine, brackish and continental facies have been recognised under the alluvium as a result of recent drilling operations by the Standard Vacuum Oil Company.. The sedimentaries, which rest on basaltic lava flows of the Jurassic age, have been found to have a thickness of about 3,292 m. at Jalangi (24°04' : 88°38'), 2,530 m. at Burdwan (23°14'-88°38') and 1,158 m. at Galsi (23°21' ; 87°39'). Thus the Lower Cretaceous vulcanicity marked the initiation of a prolonged period of Mesozoic-Tertiary basin movements in the Bengal delta. Formation of the trapwash rocks under continental, fresh water, lacustrine and lagoonal conditions continued in the late Lower Cretaceous period, until

downwarp movements resulted in marine onlap in the early Upper Cretaceous times in parts of the Bengal area. There was a periodic marine regression until a strong marine activity was initiated all over the Bengal area in the early Middle Eocene time, which lasted till the end of the Upper Eocene. There was again a widespread marine regression when another fresh marine activity took place in the late Oligocene or early Miocene time which lasted until the end of the Miocene. Marine regression and uplift were conspicuous in the Pliocene and Pleistocene times, which are believed to have been connected with the Tertiary folded belt of Tripura, with the pronounced uplift of the Shillong massif and with less conspicuous Garo-Rajmahal basement ridge. The present configuration of the Bay of Bengal is apparently a late Pleistocene to Recent feature. The beds are practically horizontal, and are low-dipping towards east and south-east. Predominant structural deformations affecting the sediments are faults, presumably of many generations.

The sub-areal weathering of the various rock formations in a monsoon climate with alternate dry and wet seasons which commenced near the end of the Tertiary era was responsible for the formation of a peculiar regolith, the laterites. These laterites are found as discontinous patches fringing various rock formations right from the Archaeans to the Tertiaries. Laterites which are known to have been formed since Cretaceous times, range up to Pleistocene in age. There are evidences as well that the process of lateritisation on the various rock exposures is continuing in optimum conditions even in recent times. With the formation and upheaval of the laterites and the filling up of the Indo-Gangetic trough by the alluvium in sub-Recent and Recent times, the configuration of the State of West Bengal has been completed.

At present, there is no glacier within the borders of West Bengal. But N. K. Kar is of the opinion that there are evidences in recognition of the Pleistocene glaciation in the Eastern Himalayas. He suggests that a huge glacial lobe encroached from over the central Himalayas down to an altitude of 152 m. in the north Bengal plains.

The topography, thus formed, was modified to present day surface reliefs through subsequent secular changes by wind, water and snow.

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CHAPTER III

GEOLOGY

The new State of West Bengal is divisible into two longitudinal, and broadly distinguishable belts according to its geological formations. The western belt, constituted by various stratigraphical units, ranging in age from the oldest Archaeans to the younger Tertiary formations, covers about 21,000 sq. km. or roughly one fourth of the total area of the State. The remaining portion is made up of a wide expanse of Recent and sub-Recent alluvial formations.

Historical

The first recorded attempt at systematic mineral exploitation in West Bengal dates back to 1774 when the first coal mine was worked by Messrs. Sumner and Heatly in the Raniganj coalfield. The occurrence of coal led to geological investigations in the State being undertaken officially in 1846 and to the foundation of a properly organised Geological Survey of India in 1851. The pioneer geological workers in West Bengal include Rupert Jones (1817), H.W. Voysey (1823), Victor Jacquemont (1829), Rev. J. Everest (1831), G. Homfray (1842) and Dr. J. Row (1844). With the increasing importance of the coal industry, encouraged by later discoveries of virgin deposits, systematic geological investigation was undertaken officially by D. H. Williams between 1846 and 1847 in thea Rniganj coalfield area. This was followed by the discovery of coal deposits in the Darjeeling district in March, 1849 by Sir Joseph Hooker during his traverses through the Himalayas. In the succeeding year, Dr. J. McClelland carried out geological investigations in the Rajmahal hills. Later, observations relating to some rocks and geological features were cotributed by H. Piddington (1850 and 1855) and Col. J. C. Haughton (1854). After the establishment of the Geological Survey of India in 1851, Joseph G. Medlicott and W. L. Wilson carried out investigations in Midnapur district, whereas T. Oldham geologically examined parts of Bankura and Midnapur districts and the adjoining areas during the field season 1857-58. During the two years that followed, W. L. Wilson and W. T. Blanford resurveyed the Raniganj coalfield area. Among the subsequent famous geological workers of the 19th century, the names of Godwin Austin, F. R. Mallet, V. Ball and P. N. Bose are worthy of note. Godwin Austins' account of the geology of the Buxa Duars area in the Jalpaiguri

district published in the journals of the Asiatic Society of Bengal in the years 1858 and 1865 is the first recorded account on the geology of the area. In subsequent years, F. R. Mallet made a detailed survey in the Darjeeling district and western Duars, which is still accepted as the basic geological work in the Darjeeling Himalaya. Following Mallet's survey in the northern district, V. Ball (1881) carried out systematic geological and mineral investigations in the western parts of the State. Besides investigating the coalfield areas, he also examined extensive fields in the Archaean tracts as well. After a lapse of a few years, the year 1890 was marked by the discovery of a number of new coal seams in the Darjeeling district by P. N. Bose. The observations of these pioneer officers are mentioned in the various publications of the Geological Survey of India.

The eastern alluvial part of this State also attracted notice in the early nineties in connection with oil exploration.

Recent Work

During the present century, geological work was focussed mainly on the western districts, *viz.*, Bankura, Midnapur, Purulia, Birbhum and Burdwan districts, and was also extended to the Darjeeling and Jalpaiguri districts in the north. The progress in the recent studies on the geology and mineral resources of the State was contributed mainly through the systematic geological and mineral investigations carried out by the officers of the Geological Survey of India. J. A. Dunn, A. K. Dey and A. B. Dutt mapped parts of Purulia and Midnapur districts during 1936-40. S. C. Chatterjee carried out detailed study of the anorthosite rocks of Bankura in 1936 and again in 1959. A. Hunday mapped considerable area in the Bankura and Midnapur districts during 1948-54, and M. R. Subramanyam continued mapping in Midnapur district in 1949. G. N. Dutt did detailed investigations of limestone in the Purulia district in 1958, while S. Sen and B. Roychowdhury did detailed work on the geology and tectonics in parts of Bankura and Purulia districts in 1959. B. C. Gupta and M. K. Roy Chowdhury did detailed prospecting of wolfram deposits in Bankura during 1941-44. Recently, after 1960, P. S. Chakravarty, M. B. Pawde, M. G. Rao, S. K. Banerjee, S. Das Gupta, S. Bandopadhyaya and many other officers of the Geological Survey of India and research workers

and professors of the Universities have done work on the Archaean geology and mineral resources in the western districts of West Bengal.

Recent work on the Archaean geology, tectonics and mineral resources in the Darjeeling and Jalpaiguri districts in North Bengal and in the adjacent Sikkim areas has been done by J. B. Auden (1935), A. Heim (1938), S. Roy (1935 and 1947), D. K. Chandra (1949), A. M. N. Ghosh (1951-52, 1956-60), G. N. Dutt (1951-54), T. Banerjee (1952-54), S. N. Sen (1951-54), S. Banerjee (1954, 1958-60), A. De (1956), T. K. Kurien (1962-63), M. B. Pawde, and many other officers of the Geological Survey of India and other organisations.

As a result of these studies, the Archaeans of this State could be sub-divided into various groups, and the regional metamorphic zones in the Archaeans could be mapped both in the western and northern districts. Representatives of the Purana (?) rocks have also been reported.

Gondwanas attracted special attention from various workers because of their valuable coal contents. E. R. Gee brought out the first comprehensive memoir on the geology and coal resources of the Raniganj coalfield in 1932. C. S. Fox gave an account of the Lower Gondwana coalfields of West Bengal in his memoir in 1934. The coalfields of North Bengal have also been described by G. E. Pilgrim (1906), A. Lahiri (1937), A. Hunday (1953-54) and M. S. Balasundaram (1955). B. C. Roy described the geology and mineral resources of the Panchet Hill in 1938, and Khedkar worked in 1949 on the limestone occurring there. A new coalfield at Barjora in Bankura district has been discovered by Hunday in 1949-50, while the detailed account of the revised work on the geology and coal resources of the Raniganj coalfield was published in 1956 by D. R. S. Mehta who also described the fire-clay deposits of the Raniganj coalfield in 1948. In 1950, A. B. Dutt, G. N. Dutt and others worked on the possible use of Raniganj coal for the manufacture of synthetic petroleum. A detailed work on the petrology and genesis of the lamprophyre intrusives of the Raniganj coalfield was done by S. Banerjee (1953). In recent years, the Geological Survey of India have undertaken detailed proving of the Raniganj coalfield by deep drilling (B.R. Narayanamurthy and others, 1957). Petrological and chemical studies of these coals have also been done by N. N. Chatterjee (1929, 1934, 1939-40 & 1955), A. K. Banerjee (1932) and P. N. Ganju (1955).

A. Hunday (1954) found out certain Tertiary formations with dicotyledenous fossil wood in parts of Bankura and Midnapur districts. D. R. S. Mehta (1946), A. Hunday (1948-53), P. K. Chatterjee (1954) and S. K. Banerjee (1961) described the Tertiary clays from the Bankura and Birbhum districts. Khedkar (1954) reported gold in the Tertiary basin of West Bengal, Bihar and Orissa. N. R. Kar (1951) worked on Pleistocene glaciation in the northen parts of West Bengal. He described the occurrence of terminal moraines and attenuated glacial boulders at an altitude of 152 m. and the extension of pre-glacial outwash to about 90 m. over the North Bengal plains. The Quaternary geology of the Bengal Basin has been described by J. P. Morgan and W. G. McIntire in 1949. Investigations for groundwater around Calcutta by A. L. Coulson (1940) and recent drilling for groundwater by the Geological Survey of India and the Exploratory Tubewells Organisation and those for oil exploration by the Standard Vacuum Oil Company in the Bengal Basin have brought a wealth of information on the sub-surface stratigraphic sequence and structure as well as the thickness of the alluvial cappings in these parts (Biswas, 1959). The work on recent sand deposits in the Damodar and Ajay river channels has been done by A. K. Roy (1942), A. B. Dutt (1946-47 & 1957-58) and S. Banerjee (1957-58). Their work has immensely helped the Coal Board and the D. V. C. regarding sand stowing in the collieries and in the flood control.

Stratigraphy

An attempt has been made here to outline the stratigraphic sequence (*vide* annexed table) with a brief description of the different geological formations. The geomorphological history of the State has already been narrated in Chapter II.

The rocky portions of this State, both to its west and north, comprise various rock groups starting from the oldest Archaean basement complex to the sub-Recent and Recent alluvium. With the exception of the vast expanse of alluvium which constitutes nearly three-fourths of the State in area, Archaeans are the most dominant rock groups found extensively over the western and northern parts of the State. The Tertiary and Pleistocene sedimentaries including the older alluvium, laterite, *Bhabar* deposits and sandstone, conglomerate and grit are the next important groups of rock found abundantly in the southern foothill region of the Darjeeling and Jalpaiguri districts and in the eastern parts of the Archaean tract in the Midnapur, Bankura, Burdwan and Birbhum districts. Gondwanas come next, occupying most of the western part of Burdwan district and small portions adjoining the Purulia, Bankura and Birbhum districts.

rmations found in the State and compiled from

	Peninsular Region
	Alluvium { Newer / Older
	and residual soils and coastal sandstones.
	Older alluvium, laterites, lateritic gravels.
	(?) Unconformity
	Gritty to medium-grained ferruginous sandstones and gravels, coarse, yellowish felspathic sandstones (occasionally with dicotyledonous fossil wood) underlain by thick clay beds of unknown thickness, Durgapur beds.
	Unconformity
Upper Gondwanas	Post-Lower Gondwana basic and ultrabasic intrusives and Rajmahal traps and inter-trappean beds.
	Supra-Panchet sandstones and (of Panchet and Biharinath hills). Durgapur beds (?).
	(?) Unconformity

	Age		Extra-Peninsular Region (Himalayan Region)			Peninsular Region
Palaeozoic	Permian		Damuda sandstones, quartzitic shales and crushed coal seam (anthracitic) (with a boulder bed near Tindharia)	Lower Gondwanas	Panchet	Panchet sandstones and shales.
					Damuda	Raniganj sandstones and shales with coal seams. Barren measures-Iron-stone shales and ferruginous sandstones. Barakar conglomerates, sandstones and shales with coal seams.
	Upper Carboniferous		——o——Overthrust——o——		Talchirs	Talchir sandstones, shales and boulder beds.
						Unconformity
	Lower Palaeozoic to Purana (Algonkian)	Buxa series	Slates, phyllites, quartzites, schists, limestones, dolomites and banded ferruginous rocks.			Felspathic quartzite of Susunia hill, gritty, quartzitic sandstones north of Beliator with quartz, aplite and pegmatite veins (within the Bankura district)
						Unconformity
Archaeans			*Darjeeling gneisses :* Garnet-biotite-schists, granulites and schists containing staurolite, garnet, kyanite, and sillimanite. —o—Transition—o— *Daling rocks :* Phyllites containing garnets, sericitic and chloritic phyllites, slates, greywackes, grits, quartzites, schists and limestones.	Purana(?)		Dolerites equivalent to Newer Dolerite of Singhbhum (Dharwar or Purana age ?).
						Porphyritic granites, pegmatites, granites and granodiorites, leptynites, migmatites, epidiorite, norite, pyroxene-granulite, amphibolite and anorthosite. Para-gneisses and schists, calc-silicates, calc-schists (containing garnet, staurolite, kyanite at places), amphibolite, sillimanite-almandined, gneisses, quartz-schists, mica-schists, quartzites, banded magnetite-quartzite and phyllite.

It also occupies a narrow strip in the foothills of Darjeeling and Jalpaiguri districts. A very small portion in the northern part of Birbhum and north-western part of Murshidabad districts is covered by Rajmahal trap.

The sedimentary exposures of Palaeozoic, Mesozoic and Cainozoic age are extremely sporadic and isolated in occurrence and distribution. The Tertiary sedimentary formations forming the eastern fringe on the Archaean shelf, in the western part of the State, continue beneath the alluvium cover as revealed from drillings' conducted by the Stanvac. Similarly, the Tertiaries at the foot hills in the north may also continue below the alluvium. The Lower Gondwana fields both to the west and to north of the State may also likewise extend over greater areas under the alluvium cover. Regional explorations by the Geological Survey of India in certain parts of the alluvial capped Raniganj (Lower Gondwana) area, and also in the newly discovered Gondwana patch in the Bankura district have revealed interesting results as to the extention of these coal bearing formations and coal seams.

In the following paragraphs, the findings under the various categories of different rock formations are briefly outlined.

ARCHAEANS

Archaeans are the oldest rock formations and the most dominant among the various rock types exposed in this State. In their areal extent, they cover approximately 3,100 sq. km. in the western part of the Sate, comprising the western portions of the Burdwan, Birbhum, Bankura and Midnapur districts and practically whole of the Purulia district. They also occur in the nortern part of Darjeeling and Jalpaiguri districts.

Detailed studies in the Archaean terrain of these districts have revealed the presence of a variety of rocks including phyllite, para-and ortho-schists, gneisses, anorthosite, various granitic rocks, epidiorites, dolerites, para-gneisses, granulites, pegmatites, aplite and quartz veins.

The Archaeans of the western part of the State is, in fact, a continuation to the east of the Peninsular Archaean tract of Chotanagpur plateau. In this terrain, the older group comprises mainly para-schists and gneisses. Amongst the para-schists and gneisses, the older group comprises the pelitic series, while the

para-amphibolites, generally standing out in relief, constitute the younger member.

The para-schists include phyllite (sometimes carbonaceous), sericite-schist, quartz-muscovite-biotite schist, garnetiferous schist, quartz-sillimanite schist, hornblende-schist, quartzite, sillimanite-schist (occasionally with flakes of graphite; khondalites), chlorite-schist, talc-chlorite-tremolite schist and actinolite-schist. These are possibly older than those belonging to the para-amphibolites group, such as hornblende-schist, calc-granulite and gneiss. Apart from these para-schists, anorthosites and norites are also noticed.

The monomineralic rock, the anorthosite, composed almost exclusively of labradorite felspar with rarely five per cent. of femic minerals, stretches as a lens-shaped body covering an area of over 148 sq. km. in the western portions of the Bankura and in the adjoining Purulia districts. Scattered through the anorthosite body as well as in the surrounding areas are found a number of exposures of basic rocks, *viz.*, para-gneisses and granulites, such as hornblende-gneiss, pyroxene-gneiss, pyroxene-granulite, pyroxene-amphibolite etc. These anorthosites, identified by Sir Thomas Holland in 1898, received considerable attention later by S. C. Chatterjee who thinks that they are of primary magmatic origin as these have crystallised gradually from a parent gabbroid magma, and in its semi-solid state has been injected as a sheet like body into the granite gneiss. According to him, the anorthosites found about five to six kilometres south of the main body outcrop as dykes in the granite gneiss. The pyroxene (diopside) granulites with garnet corona etc. are due to the effects of subsequent metamorphism. This was followed in the final phase by amphibolisation, cataclasis and hydrothermal metamorphism. Later work by Hunday in this belt and adjoining areas revealed the presence of more outcrops of similar rocks in the granitic country as far south as 40 km. from the main anorthosite mass. He could not discern any intrusive effect of the anorthosite on the granite gneiss, but found pegmatites and small veins of aplite and quartz in the main body as well as in the dyke-like bodies of anorthosite near their contact with the granite gneiss. Sen and Roy Chowdhury (1959), who made subsequent studies on anorthosites, are of the opinion that the mineral assemblage may have been formed by high grade metamorphism of alumino-calcareous sediments, which view has also been shared by P. R. J. Naidu.

In the para-schists and schists, Hunday recognised regional metamorphic zones including sericite-, chlorite-, muscovite-, biotite-, and garnet-zones in the Bankura district. The grade of regional metamorphism was found to increase successively from north to south. S. N. P. Srivastava and S. K. Ramaswami of the G. S. I. found out that the garnet-zone is followed further south by staurolite-, and kyanite-zones in the Midnapur district.

The granitic rocks include grey, banded biotite-granite gneiss or migmatites (which are possibly representative of Chotanagpur granite gneiss), pink granite, gneiss, leucocratic granite gneiss, aplitic granite gneiss, quartzo-felspathic gneiss, felspathic gneiss and various granitised gneisses formed by grnitisation of the different para-schists and gneisses.

Intruded into these granitic rocks, as well as the older schists and gneisses and basic rocks, are a number of pegmatites (sometimes mica bearing), aplite and quartz veins which are abundant in their distribution throughout the Archaean tract. Amongst these later intrusives are the schorl rocks which sometimes attain gneissose structure known as schorl gneiss which constitute hills at places, like Masak Pahar in the Bankura district along a conspicuous fault zone.

Besides the basic rocks mentioned above, which occur mostly in anorthosites and granite gneisses, a number of younger dolerite and meta-dolerite dykes have been found as intrusives in the country occupied by granite gneiss and anorthosite. All these dolerite dykes are possibly related to the "Newer dolerite" of Singbhum district of Bihar as described by Dunn and Dey. There are, however, some medium to coarse-grained dolerite dykes traced over a distance of 34 km. arranged *en echelon,* in an alignment of N.N.W.-S.S.E. right upto the boundary of the Gondwana coalfield in the Bankura district, which may be equivalent in age to the dolerite dykes of the coalfields. The coalfield dolerites are usually considered as representatives of the minor intrusive phase of the Rajmahal lava flows of Jurassic times, although Sir C. S. Fox suggested that these may be related to the Deccan Traps and consequently be of Cretaceous age.

The regional foliation dips of the granite gneiss and the metamorphites of the Bankura and Puruliá districts are usually at steep angles towards north, although local southerly dips are also noted. In the para-schists, however, southerly foliation dips, at fairly steep angles are not uncommon. Presence of regional folds are suggested. In the

Purulia district in particular, the regional structure as deciphered by Dunn, Dutt and P. S. Chakravorty indicates presence of isoclinal overturned folds having almost horizontal or low east-west plunging axes. As a result of cross folding, a certain amount of swinging in the fold axes from East—West to W. N. W.—E. S. E. is also reported at places (Chakravorty, 1960). In the Bankura and Midnapur districts, particularly in the southern parts, where the Archaeans comprise both ortho- and para- schists and gneisses apart from intrusives, and the fold axis of the Eastern Ghats which is in the N.N.E—S.S.W. direction makes acute angles with that of the Dalma syncline which is in the east—west direction, the beds are overfolded plunging generally towards N.N.E.

In this Archaean tract in the western part of the State, a number of faults have been recognised, of which the one trending almost east-west for a distance of 27 km. was found to continue in the Bankura district in proximity to the northern boundary of the para-schist country with the granite-gneiss. This fault zone is the eastward extension of the to the west one noted earlier by Dunn and Dey in the Purulia (Manbhum) district. This fault zone comprises a number of conspicuous hillocks or ridges either composed of schorl gneiss or cherty quartz and quartzite with sporadic concentration of secondary iron-ores as noted in the Bankura district. Wolfram and scheelite occur near this fault zone (Hunday, 1950-53).

The rocks in the northern part of this State comprising the Darjeeling gneiss and Daling schist, slate and phyllite are considered by some to correspond to the Dharwars, while some are of the opinion that these might belong to Puranas. Rocks of the Daling series, phyllites including sericite-, and chlorite-phyllites, slates, quartzites, greywackes, conglomerates, flagstones, siltstones, and schists including chlorite-, biotite-, garnet-, and muscovite-schists, apparently rest on the Damudas. This inverse sequence may be due to some overthrust between the Dalings and the Damudas, or else, at least, a part of the Dalings may be representing the metamorphosed equivalents of the Damudas as postulated by S. Roy (1935). The Dalings occupy a large area in the Tista valley and continue northward into Sikkim where they from a dome below the Darjeeling gneiss. In the Tista valley the Dalings are about 13 km. wide separating the Darjeeling and Kalimpong hills which are composed of Darjeeling gneiss and granites. The apparent younger position of the Darjeeling gneiss, exposed only on the high hills and ridges, is explained by the presence

of a thrust between the Dalings and Darjeelings by Dyhrenfurth and Wager (quoted by Dey, 1956). Heron's (1934) earlier postulation as to the presence of recumbent folds and reversed faults resulting in inversion of strata was later endorsed by A. M. N. Ghosh (1951-52 & 1956). He observed that the gneissic rocks in the Sikkim area were subjected to great folding movements and the immense fold in that area simulates the shape of a gigantic horse shoe, the eastern and western limbs dipping eastward and westward respectively, while the folds to the north dip northwards. Latest views by some are that the boundary is transitional.

The Darjeeling gneiss is exposed north of Khairabari (26°48′ : 88°13′) near the Nepal border, north of Gayabari and Mahanadi railway stations and Sukna forest, west of Mongpu (26°58′ : 88°22′), east Samthar (26°59′ : 88°30′) and north of Nimbong (26°58′ : 88°33′) in of the Kalimpong hills including the hill resorts Darjeeling, Kurseong, Jorebunglow, Sukhiapokhri and Kalimpong. The gneiss is well foliated, much folded and crumpled, especially near Darjeeling where the prevalent strike is W.N.W.—E.S.E. Biotite-gneiss at places develops 'augen' structure. A sheared intrusive granite (called 'Lingtze Granite') is found in the Kalimpong hills. Besides these, there are pegmatites and quartz veins intruding within these formations.

A number of regional metamorphic zones of chlorite, biotite, garnet, kyanite and sillimanite were recognised by Auden (1935) and Roy (1935) in certain sections of the Darjeeling Himalayas. Subsequently G. N. Dutt (1950-54), T. Banerjee (1950-54), A. Hunday (1953-54), S. Banerjee (1954, 1958-60), A. De (1956) and T. K. Kurien (1962-63) continued detailed mapping in the Darjeeling Himalaya and in the adjacent Sikkim areas.

Minerals in the Archaeans.—The important economic minerals so far known to occur in the Archaeans of West Bengal are fairly numerous. These include gold, tungsten (wolfram and scheelite), clays, lead and zinc, copper, silver, pyrite, arseno-pyrite, ilmenite, iron-ores, radioactive minerals, kyanite, sillimanite, limestone, dolomite, mica, vermiculite, talc-steatite etc. Occurrences of some of these are important and are being exploited while more work will be necessary to assess the potentiality of the others. These mineral occurrences are further discussed in a later section of the report and under relevant individual heads.

PURANA ROCKS

Although no undoubted Purana rocks have yet been reported from the peninsular region of the State, it is possible that the following occurrences suggested by A. Hunday, may be of Purana age. These are located in the Bankura district and include :—

(i) outlier of the quartzite of Susunia hill,

(ii) small exposure of quartzitic gritty sandstones (first reported by A. Hunday) near the second milestone on the Beliatore—Durgapur road to the north of Beliatore railway station.

The quartzite of the Susunia hill shows certain discordant dips (20° to 30° N.N.E , through E.N.E., as well as to the east), although the actual contact of the quartzite with the Archaeans is not discernible since the base of the hill is covered by the debris of rolled down material. The presence of intrusive quartz and pegmatite veins in the Susunia quartzite was also noticed.

These quartzites, however, show some degree of resemblance to the quartzites forming the Koura hill, ten kilometres to the east, which are associated with the mica-schists and grouped under the Archaeans.

In respect of the sec-nd occurrence, which is composed of quartzitic gritty sandstone, no structural evidence as regards discordant dip or unconformity has so far been revealed to confirm a possible Purana age.

In the extra-peninsular region, the age of the rocks of Daling series, which overlie the Lower Gondwanas along a thrust contact and now placed under the Archaeans (Dharwars), is controversial. There are however, some opinions favouring its Purana to Lower Palaeozoic age.

The Buxa series comprising predominantly of dolomite, dolomitic limestone and phyllite and also of quartzite, talc-, chlorite-schist, banded ferruginous rocks, chlorite-quartz-magnetite schist, occur in the northern part of the Jalpaiguri district. These rocks appear to overlie the Lower Gondwana rocks along a thrust contact. The Buxa rocks are generally assigned a Purana age and also considered by some workers as belonging, at least in part, to an younger age.

GONDWANAS

The Gondwanas form the main undoubted representatives of subsequent sedimentation that continued throughout the Palaeozoic (since Upper Carboniferous) and Mesozoic eras.

The Gondwana rocks, which cover an area of only about 88 sq. km. in the Himalayan region and the rest 1,243 sq. km. in the peninsular tract, are second only to the Archaeans in their areal extent in the State excluding the wide stretch of the Ganga alluvium.

The Gondwanas are found as small basins formed by trough faulting in the older rocks during the post-Purana period. The deposition of these fluviatile sediments in the gradually sinking basins or troughs is responsible for their enormous thickness seen in the peninsular region and also for the preservation of their valuable coal seams from erosion and from the effects of crustal movements. This contributed in retaining the continuity of such deposition and the strata are found as low dipping beds almost in their original order of deposition.

Peninsular region

The Gondwanas comprise enormously thick deposits in the peninsular region, the strata attaining a thickness of over 3,230 m. (10,600 ft.) as seen in the Raniganj coalfield. The Gondwana terrestrial deposits, which have a glacial boulder bed at the base, comprise a thick series of shales and sandstones (frequently fossiliferous) with intercalations of coal seams. These immense deposits which range in age from the Upper Carboniferous to the Lower Cretaceous have been sub-divided into a number of series, *viz.*, Talchir, Damuda, and Panchet forming the Lower Gondwanas, and Mahadeva, Rajmahal and Jabalpur constituting the Upper Gondwanas, on the basis of their entombed animal and plant remains and also depending on the characters of their sandstones and shales particularly in the peninsular region of the State.

The Lower Gondwanas are mainly confined to the Raniganj coalfield area of the Burdwan district, which extend into adjoining parts of Bankura and Purulia districts south of the Damodar river and Trans-Ajoy coalfield and also occur as a detached basin namely the Tangsuli basin in the Birbhum district.

Barjora coalfield

In the Bankura district, another coalfield known as Barjora coalfield has been discovered by A. Hunday during 1949-50 and 1951 to the south of the Damodar river and south-west of Durgapur. This new field covering about 16 sq. km., consists of exposures of Lower Gondwana age which constitute fossiliferous felspathic and ferruginous sandstones and grey and red shales with a pebbly horizon, and according to, Hunday, the field to extends over a large area under the alluvium, Tertiaries and laterites. The fossils discovered in this new patch by Hunday and described by K. Jacob, include *Glossopteris indica, G. communis, G. retifera, Gangamopteris cyclopteroides, Samaropsis raniganjensis, Vertebraria and Cordaicarpus* sp. suggesting their probable Barakar age, and this patch was suggested to be potentially coalbearing by Hunday. The extension of this Lower Gondwana patch, was confirmed over an area of 34 sq. km. between the latitudes 23°15′ and 23°27′ and the longitudes 87°13′ and 87°18′. This patch was confirmed to contain about 25 millon tonnes of Class III coal (inferior grade). The Talchir rocks were not encountered in this field.

Raniganj coalfield

The Raniganj coalfield, a principal coalfield of the State, extends beyond the limits of the State. The present proved limits of the field are included between the longitudes 86°36′ and 87°20′. This largest coalfield of the State is the second largest producer of coal in India, contributing about 33 per cent. of India's total coal production. The major parts of the coalfield lie to the east of the Barakar river within the district of Burdwan and with slight extensions to Bankura, Birbhum, Purulia districts of West Bengal and to the Manbhum district of Bihar. This coalfield, which is the easternmost field of the Damodar valley coalfields, is located 200 km. north-west of Calcutta.

The known coalbearing areas of the Raniganj coalfield cover 1,500 sq km., of which the western part of the field, to the west of the Barakar river includes 34.68 sq. km. The tract south of the Damodar river extends 256 sq. km., while the major part of the field covering about 1,100 sq. km. lies between the Damodar and Ajoy rivers and to the east of the Barakar river. The narrow strip of the coalbearing rocks to the north of Ajoy, comprises the remaining 114 sq. km.

The coalfield is bounded on its three sides by Archaean rocks, while the fourth side is covered by alluvium and laterites. The extension of the field below the alluvium to the east, has been proved by recent drilling carried out by the Geological Survey of India, particularly in the Ondal area.

The first systematic survey of the field was made by D. H. William in 1845-46 and in 1850, followed by W. T. Blanford, W. L. Wilson, H. Walker and R. R. Simpson during 1908-13, and by C. S. Fox, S. Sethu Rama Rau, E. R. Gee and A. K. Banerjee during 1925-28. In recent years, much of the attention of the Geological Survey of India was focussed in proving the extension of the field under the alluvium and also in respect of revision of the coal reserves, since 1953.

The coalfied extends for about 58 km. along south-west, of which about 39 km. lies' within the limits of the State. The width of the field varies between 19.3 and 30.5 km. The extension of the field at least upto Dubchururia (23°35′: 87°14′), which is about four kilometres north-east of the Ondal railway station, has already been proved through deep drilling by the Geological Survey of India. The coalfield is traversed by the Damodar river, along its southern-half and by its two tributaries *viz.*, the Barakar and Ajoy, which together form the main drainage pattern of the area. In the coalfield, the Panchet (.643 m.), Biharinath (.450 m.) and Gourangidih (.290 m.) are some of the prominent hills, composed of Upper Gondwanas.

General structure.—Over a greater part of the field, the dip of the beds is in a southerly direction, due to which the oldest rocks, the Talchirs are exposed adjoining the northern boundary. These are followed successively southwards by the next group of younger rocks. The strata dip towards south and south-west at angles ranging from 2° to 35°. Except in some limited tracts in the north-eastern part of the field, the northern boundary of the basal Gondwanas and the metamorphics is along a line of natural deposition, complicated by later faulting. The Barakars overlap the Talchirs in the north-eastern end of the field. In the case of the southern boundary, which is a well defined fault line, various rocks of different horizons are exposed adjoining the crystalline gneisses. Faulting is also noticed in the west.

According to E. R. Gee, there is no evidence to suggest that the area of gradual subsidence and accompanying sedimentation in

the Raniganj coalfield was limited by any tectonic structures, either rift-faults or pronounced folds, and that the present tract of this coalfield represents only a very small portion of the original area of Gondwana sedimentation. It owes its preservation to the fact that it has been subsequently faulted down within the Archaean land mass and thus has been protected against effects of weathering. It is further stated that the main complex boundary fault, which is a series of strike faults arranged *en echelon* forming the southern and western limits of the coalfield, has a downthrow of about 2,740 m. (9,000 ft.) in the vicinity of the Panchet hill. In the extreme north-eastern part of the coalfield, the large oblique strike fault following the Ajoy river with a downthrow to the north-east is responsible for the preservation of the Trans-Ajoy Gondwanas. A number of oblique dip and sag faults apart from strike faults are noticed in the field.

Since the major displacements affected the Lower Gondwana rocks and the Supra-Panche, they might have occurred later, say during Jurassic times, than the minor faulting and folding which may have commenced durey early Gondwana times.

The complete succession of the strata of Raniganj coalfield is given in Table 1, after E. R. Gee.

TABLE 1.—Succession in Raniganj Coalfield.

Recent and sub-Recent	Alluvial and lateritic deposits.	
Upper Gondwanas (?) 305 m. (1,000 ft.)	Supra-Panchets (of Panchet hill etc.) Coarse, red, yellow and grey sandstones and quartzose conglomerates, with bands of dark red shales.	Fragments of stems and fossil-wood.

(?) Unconformity————————————————

Lower Gondwanas	Panchet series 610 m. (2,000 ft.)		Coarse, yellow and grey, soft, micaceous false-bedded sandstones, with thick red clays; khaki-green shales and sandstones at the base.	Plant-remains (including several types distinct from the Damudas) *Glossopteris*, *Schizoneura*; also reptilian and fish remains, *Estheria (Posidonia)*.
	Damudas series.	Raniganj measures 1,036 m. (3,400 ft.)	Mainly fine and medium textured, grey and greenish false-bedded, felspathic sandstones, with shales and coal seams.	Plant-remains ihcluding *Vertebraria*, *Trizygia*, *Glossopteris*, *Pecopteris*, *Schizoneura* *Phyllotheca etc.*
		Ironstone shales 366 m. (1,200 ft.)	Black carbonaceous shales with occasional sandy micaceous shales. (with numerous bands of clay ironstones.	Plant-remains abundant, though not well preserved. *Glossopteris etc.*
		Barakar measures 640 m. (2,100 ft.)	Coarse conglomerates, with white and gray sandstones often false-bedded; shales and coal seams of variable character.	Plant-remains Including *Glossopteris*, *Gangamopteris*, *Vertebraria*, *etc.*
		Talchir series 274 m. (900 ft.)	Coarse sandstones, white or slightly variegated at the top; fine khaki-green and blue green shales with sandy shales and fine green sandstones including undecomposed felspar; at the base is a boulder bed, including boulders up to 4.5 m. diameter.	Plants very rare; a few stems, seeds etc.

Unconformity— —

Archaeans.

The Raniganj coalfield was regionally proved to extend below the laterites and alluvium over a greater area beyond its previously known limits. The extension of tho coal seams of the field, eastward was found in the Ondal aroa. Previous workers (Gee, 1952) suggested its possiblo existenco upto Durgapur area.

Igneous Intrusions :—Gondwana rocks of tho Raniganj coalfield are intruded by a large number of igneous intrusions comprising the doleritic or basaltic dykes and ultrabasic mica peridotite and lamprophyre dykes and sills.

Of the dolerito dykes, the names of some prominent ones, *viz.*, the Salra dyke (width 46 m.) and the Narsunuda dyke, the Sitarampur dyke and the one through Charanpur colliery may be mentioned. These dolerite dykes, which were in most cases found to be unaffected by faulting, have been correlated with the volcanic basalt of the Rajmahal hills, as not older than Lower Jurassic. According to Fox, they may belong to the Deccan Trap flows and hence may be of Middle Cretaceous age.

Since the ultrabasic intrusives are intimately connected with the faulting of the area which affected the supra-Panchet strata (of suggested Rhaetic age), they are not older than the Lias. According to E. R. Gee, the evidence in the Raniganj area at least indicates a sequence of events in the following order :—

(i) earth movements resulting in the major displacement of the Gondwana strata followed by ;

(ii) the intrusion of the ultrabasic (mica-peridotite and lamprophyre) series ; and

(iii) the intrusion of the dolerite dykes and sills, definitely subsequent to the faulting.

In the Damodar valley coalfields, profuse intrusions of sills and dykes of lamprophyric and doleritic rocks into the shales, sandstones and coal seams are noticed. According to S. Banerjee (1953) lamprophyres in the Raniganj coalfield may be differentiated in to the following rock types.

1. Biotite-peridotite
2. (a) Biotite-lamprophyres
   - (i) with olivine
   - (ii) normal type (minette and kersantite)
   - (iii) with olivine, pyroxene (pigeonitic diopside and acmite), and soda-amphibole

(iv) with olivine and leucite

(v) with olivine, leucite, pyroxene and amphibole.

(b) Lamprophyre with feldspar and olivine only

(c) Biotite-olivine-leucitite

3. Micro-syenite

4. Quartz-carbonate rock.

He has also discussed about the probable existence of a lamprophyric magma. The euhedral olivine crystals may be xenocrysts connected with the nearby Rajmahal lava flows. He does not suggest a late crystallisation of biotite as viewed by Sharma and Subramanyan (1951).

These intrusions are probably the representatives of the volcanic activity which occurred during the post-Lower Gondwana period during the Jurassic time and manifested itself into the outpouring Rajmahal lava flows about 48 km. north of the Raniganj coalfield in the Birbhum district.

The Rajmahal series of the Upper Gondwanas consist of 610 m. thick bedded basalts with about 30.5 m. of inter-trappean beds consisting of siliceous and porcellanoid carbonaceous clays and sandstones. These dykes and sills have burnt the coal seams near their contacts producing *jhamas* much to the deterioration of the coal seams.

Trans-Ajoy Coalfield

The portion of the Raniganj coalfield north of the Ajoy river from Pariharpur (23°50′ : 87°03′) eastwards to Pajera (23°45′ : 87°19′) is referred to as Trans-Ajoy coalfield by C. S. Fox. Only the Barakar series containing thick Kasta and Paharpur seams is exposed in this strip.

Recently S. Bandopadhaya (1959) has described Karharbari aspect of some Lower Barakar rocks around Palasthali, (23°50′:87°04′) from a collection of plant fossils from them consisting of *Rhipidopsis* sp. and a few other varieties of the same genus, two species of *Sphenopteris*, *Buriadia sewardi*, *Noeggerathiopsis* sp., *Taeniopteris danaeioides*, *Gondwanidium* sp.

Tangsuli Basin

A small outlier of Barakar rocks consisting of pebbly sandstones, grits, sandstones and carbonaceous shales with thin stringers of coal is exposed over an area of about five square kilometres lying

between the Brahmani and Ajoy rivers and on the north of the More (or Mayurakshi) river, a few kilometres north-west of Suri (23°55′:87°32) and north of the Tangsuli village (23°58′:87°29′) in the Birbhum district. The Talchirs are absent and the boundaries are somewhat obscured by laterite. Other Gondwana fields are also situorted close to the Tangsuli basin. About 32 km. south-west of Tangsuli are the Damuda rocks of the Ajoy river, and the nearest exposure of the Barakar coal measures to the west is in the Kundit-Karaia field less than 48 km. away, with an outlier of Talchirs in between. The minimum distance of Rajmahal traps and Dubrajpur beds from the Tangsuli outlier is about 11 km. to the north-east of Deocha (24°02′:87°35′) on the Dwarka river. C. S. Fox, while reporting on the extension of the Gondwanas to the south from the Ganga river below Colgong, also suggested a probable connection of the Lower Gondwana rocks of the Rajmahal area with those of the Raniganj and Giridih fields.

The probable extension of the Gondwanas under the alluvium, within the Bengal basin, is suggested by the recent finding of Gondwana rocks at a depth of 2,438 m. near Bogra in East Pakistan.

Extra-Peninsular area

The Gondwanas of the extra-peninsular areas in the sub-Himalayan region, on the other hand, were caught up in the folding movements culminating into recumbent folds and overthrusts that occurred during the Himalayan orogeny as suggested by their powdery and crushed coal seams, their high dips and present position. Thus, these folded Lower Gondwana rocks of the sub-Himalayan region in the Darjeeling and Jalpaiguri districts, appear to overlie the younger Tertiary beds and dip at high angles to the north below the Dalings, and Buxa series, along thrust contacts.

The coal is crushed, crumpled and somewhat anthracitic. The collieries in the Darjeeling district are located in the Lish and Gish river valleys.

Recent survey indicates that a belt of Lower Gondwana rocks is traceable from the Kosi river in Nepal to Eastern Bhutan. The coal seams are severaly crushed and dislocated in most cases. The strata are inverted, and only the overfolded limbs of the beds have so far been met with. The dips are steep and

towards the north. Occurrence of mica peridotite and lamprophyre intrusives is noted in the seams of the Darjeeling district. The fossil impressions including *Glossopteris, Vertebraria* and *Schizoneura* suggest a Raniganj age for the coal measures. But C. S. Fox, from his observations on the three kilometre wide outcrop near Tindharia (26°51′:88°23′) which has a conglomeratic horizon at the base, is inclined to regard this strata as probably Barakar in age.

Economic minerals in Gondwanas—The Gondwanas are rich in coal resources. Apart from coal, they are also the source of fire-clays and other types of clay, iron-ore, building material, road material and *kankars* (calcium carbonate concretion).

TERTIARY ROCKS

The existence of Tertiary rocks is known both in the peninsular and extra-peninsular regions of the State, and these occurrences in either regions are considered to be of Miocene age. After the Upper Gondwanas, no strata equivalent to the Lower Tertiary, *i.e.* Palaeocene to Oligocene, have been reported to occur in this State. This indicates the presence of a great hiatus in sedimentation dating since the post Gondwana period.

In the extra-peninsular regions, in the *Terai* region, in the northern parts of the Jalpaiguri and Darjeeling districts, there is a belt of alluvial detritus consisting of coarse, hard, red sandstones and shales and pseudo-conglomerates. The southern limit of exposures of the Siwaliks, a considerable portion of which lies hidden under the Ganga alluvium is, however, uncertain. On the basis of their entombed animal remains, the lower Siwalik sediments, fringing the foothill zone of the Darjeeling Himalaya and lying along a thrust contact under the older Lower Gondwana rocks, are assigned a Middle Miocene age.

The Siwaliks were involved in the later phase of the Himalayan orogeny which caused great faulting and reversal of succession of these fluviatile sediments. The most important of these overthrusts is termed as the "Main Boundary Fault". These thrusts are considered in some cases as to mark the limits of the deposition of the older series. The Siwaliks are seen in an abnormal juxtaposition with the Gondwanas, at places, occurring below them.

In the peninsular region of the State, small patches of the Tertiary grits and gravel beds, occasionally with clays and dicotyledonous

fossil wood, have been reported from parts of the Midnapur, Burdwan, Bankura and Birbhum districts.

In the Midnapur district, J. A. Dunn (Dunn & Dey, 1942) reported small patches of Tertiary grits and gravel beds commonly occurring below a thickness of 2.5 to 4.5 m. of alluvium which, according to him, extends towards the coast beneath the laterite.

In the Bankura district, Hunday (1954) mapped patches of Tertiary formations comprising ferruginous yellowish sandstone and red shale occasionally associated with quartz gravel beds and underlain by clays at a number of localities. Fairly large specimens of dicotyledonous fossil wood were also collected by him from these beds. These patches were found under a thin capping of alluvium or laterite. These beds are generally flat but local dips to the south of the order of 25° to 40° have also been recorded. Similar beds were also noted by him in course of certain traverses in the Bankura, Birbhum and Midnapur districts of West Bengal and in the Mayurbhanj district of Orissa. In the Burdwan district, the dicotyledonous fossil wood was collected in the Tertiary exposures near 11½ mile post on the western side of Panagar and Allambazar road and angiospermous fossil wood in the Tertiary exposures 3.2 km. south-west of Suri in the Birbhum district. Similar occurrences are also noted in a well section near Bolpur, Muhammad Bazar in the Birbhum district and Garbeta in the Midnapur district. These apparently isolated patches of Tertiary rocks over a wide belt suggest the presence of a continuous belt of Tertiary rocks in this part of the State.

Hunday (1954) also recorded resemblance of these formations as noted in the Bankura district and in parts of the Midnapur district to the formation overlying the Baripada limestone (Miocene) in the Mayurbhanj district of Orissa and thought that these might be equivalent to the rocks of the Tipam series of Assam. He has suggested that a belt of Tertiary rocks, mostly covered by alluvium, exists right from the eastern part of Orissa through Mayurbhanj and Balasore (where Tertiary fossils have been noted) along the western border or the West Bengal plains as far north as Bolpur in the Birbhum district. He further suggested that the Tertiary formation may not belong to the same facies all through; the marine facies may change to the fresh water facies through estuarine deposits when traced from the south to north. Extension of the marine facies to the north, underlain by Tertiary rocks, has also been

considered likely. Similarly, in consideration of the existence of a similar Tertiary formation in Burma along the eastern boundary of undivided Bengal (now East Pakistan) together with these newly found Tertiary rocks in the State, extension of the Tertiary belt under the intervening wide stretch of Ganga alluvium was postulated.

The Durgapur beds consisting of laterite, sandstone, felspathic grits and mottled clays are considered, at least, in part to belong to the Upper Tertiary age. Possible existence of Tertiary rocks under Calcutta were also suggested by Coulson (1940, p. 21).

Of late, the Tertiaries have attracted special attention in connection with oil exploration, since undertaken in India on an extensive scale. Thus deep drilling was undertaken by M/s. Standard Vacuum Oil Co. in the Bengal basin in 1959. Apart from this, the Exploratory Tubewells Organisation under the Ministry of Food and Agriculture, carried out moderately deep drilling in certain portions of alluvial stretch of West Bengal. As a result of these recent sub-surface explorations, quite an interesting assemblage of data reflecting the depth of the alluvium, nature of the underlying bed rocks and structure of the Bengal basin were brought to light. The Bengal basin including the coastal parts of Orissa and Sunderbans and excluding East Pakistan, is reported to cover an area of about 77,700 sq. km. (30,000 sq. miles). It is bounded in the north by a buried ridge running east-west between the Rajmahal and Garo Hills. The drilling data of the Exploratory Tubewells Organisation from Mandilpur (24°04' : 88°09') in the Malda district and from Buniadpur (25°23': 88°24') in the West Dinajpur district revealed the presence of granite gneiss at respective depths of 260.6 m. and 307.2 m. where the possible Tertiary sediments are met with at a depth of 198 m. from the land surface. Top portions of the possible Tertiary sediments have also been met with at depths of 91.4m. and 176.7m. respectively at Nawada (23°54':88°27') and Takipur (23°52':88°15')in the Murshidabad district, at 152.4 m. and 137 m. respectively at Debagram (24°41' : 88°19') and Bhatjangla (23°23' : 88°30') in the Nadia district, at 183 m. and 189 m. respectively at Algaria (22°45': 88°30') and Kamarkulla (23°03': 88°46') in 24-Parganas, at 152.4 m. and 106.7 m. respectively at Rupatganj (23°19': 87°25') and Panchal (23°14' : 87°18') in Bankura district, where at the latter place the bed rock is met with at 280 m. and at 76 m. depth at Dhobaberia (22°52' : 87°23') in Midnapur district (G. C. Chaterjee and others, 1962, p. 43). At Gardenreach, near Calcutta, at a depth of 810 m., a bed of sandstone

and clay has been encountered (G. N. Dutt, 1962, p. 38). Seismic reflection survey by L. N. Kailasam (1954, pp. 113—114) has also pointed out that the thickness of the alluvium ranges between 762 and 914 m. from the surface in the Barasat (22°43′ : 88°29′) area near Calcutta. Bed rock was also encountered beyond the eastern fringe of the Chotanagpur plateau in the Bankura district, where Tertiary rocks resembling the Cuddalore and Rajahmundry sansdtones have been encountered below the laterites of Pleistocene age. Some microfossils and shark teeth have also been collected from these rocks (Poddar, 1962, p. 12).

In the Bengal basin, the sub-surface data collected through deep drilling revealed the existence of Tertiary rocks with all major divisions. The different facies including marine, estuarine, brackish and continental have been recognised. The sandstone, shale and fossiliferous limestones were found to constitute the Tertiary formations. *Nummulites* and *Assilina* are characteristically found in these limestones at some places. The sedimentaries were found to overlie basic lava flows (tholeiitic plateau basalts in local association with andesite, tuffs and greenstones). These lava flows are presumably of late Jurassic to Cretaceous age. The sedimentaries were found to have a thickness of 3,354 m. at Jalangi (24°04′ : 88°38′), 2,530 m. at Burdwan (23°14′ : 87° 55′) and 1,158 m. at Galsi (23°27′ : 87°39′) as revealed in the test wells (Biswas, 1959).

The stratigraphic section obtained in the Jalangi well, the third wildcat, is considered by the Standard Vacuum Oil Company to be a typical section. The stratigraphical units of the Jalangi well are given in the Table 2 below (Basu, 1962) :—

TABLE 2

Formation and thickness	Member and thickness	Lithology	Age
Jalangi Formation 8 216·4 m. (710 ft)		Medium and coarse-grained loose sands, very coarse and gravelly at the base.	Recent-Sub-Recent
Jalangi Formation 7 1302·25 m. 4,273 ft.)	C 318 m. (1,043 ft.)	Massive medium-grained sands with pale buff silt-clay alternations.	Pleistocene-Pliocene
	B 709·25m. (2,327 ft.)	Alternate grey silt and clay with cross-bedded sands.	
	A 275 m. (903 ft.)	Thin alternation of medium to fine-grained grey sands and silty clays, coarse sands and conglomeratic bed towards the bottom.	

TABLE 2 (Contd.)

Jalangi Formation 6 616·3 m. (2,022 ft.)	C 350·5 m. (1,150 ft.)	Coarse to medium-grained, mottled, Poorly sorted sandstone with minor streaks of lignitic claystone.	Miocene-Oligocene
	B 146·3 m. (480 ft.)	Medium-grained, well sorted, slightly glauconitic sandstones, minor lignitic shales and olive shales.	
	A 119.5 m. (392 ft.)	Medium-grained, poorly sorted, ochreous, limonitic and hematitic sandstones with alternations of lignitic shales, occasional clay shales and ferruginous shales.	
Jalangi Formation 5 289 m. (948 ft.)	B 20.7 m. (68 ft.)	Grey-black shaly limestone, calcareous shales and shales, nummulitic in part.	Upper and Middle Eocene
	A 268·3 m. (880 ft.)	Nummulitic-algal limestone with dark grey to black marly breaks.	
Jalangi Formation 4 680·4 m. (2,232 ft.)	B 312 m. (1,023 ft.)	Carse, medium and fine friable white sandstones with dark shale and lignitic coal beds abundant in the upper part, associated with asphalt, sulphur stain in the lignitic coals, some resin.	Middle and Lower Eocene
	A 368·4 m. (1,209 ft.)	Coarse to medium kaolinous sandstones, slightly calcareous at the base, strongly current-bedded with primary slumping in the middle, with minor black coaly shale intercalations.	Palaeocene-Upper Cretaceous
Jalangi Formation 3 120·4 m. (395 ft.)	B 64 m. (210 ft.)	Dirty white, pinkish white and greyish white calcareous shell-bearing sandstones with some black shale and coal.	Upper Cretaceous
	A 56·4 m. (185 ft.)	Grey to dark grey shell limestones grading upwards to black carbonaceous shales, with black organic shales and coal in the lower part.	
Jalangi Formation 2 129·5 m. (425 ft.)		Red shales and red sandstones grading upwards to black carbonaceous shales associated with anhydrite and disseminated calcium carbonate at the top.	Upper-Lower Cretaceous
Jalangi Formation 1 216 m. (709 ft.)		Greenish, fine-grained, amygdaloidal basaltic lava flows, relatively minor greenstones and light grey fine-grained tuff in the upper part.	Lower Cretaceous

The basaltic lava flows (Jalangi formation 1) were encountered at a depth of 3,008 m. (9,870 ft.) at the Ghatal (22°42′ : 87°40′) well.

The sub-surface features of the Bengal Plain, as indicated by reflection seismic surveys, exhibit a gentle homoclinal feature. Considerable faulting is indicated in the western area. Major faulting is not recorded in the eastern area. The western area is divisible into two zones. Major basement scarps are present in the western zone. The eastern part shows fault features. Possible traps in this area have been tested in wells at Galsi, Jalangi, Debagram (23°41′ : 88°18′) and Burdwan with negative results. The Eocene hinge zone is inferred to the east of the Jalangi-Debagram-Burdwan trend. Some structural nosings (Memari) and a few closures (in the Ranaghat area) are also indicated by the seismic map (E.G. Jones, 1962, p. 30). A permeable sand with gas show has been found in Ranaghat-1 drilling.

Although certain portions of the Bengal basin have been investigated by now, on a regional scale, for oil by M/s. Standard Vacuum Oil Co., the search for oil or for natural gas in this alluvial tract cannot be considered as exhaustive.

It is understood that the Oil and Natural Gas Commission have now started exploration in the Bengal basin for oil and/ or natural gas; the latter alone seems to be more likely present as suggested by initial prospectors, who did not find any oil in the test-wells, so far drilled.

Besides forming a potential source for petroleum and natural gas, which are being explored, and also for building materials like sandstone, laterite and gravels, the Tertiary rocks in the extra-peninsular region of the State are reported to contain certain minor deposits of lignite, limestone and iron-ores, some of which may need further examination to prove their potentialities.

The possibility of finding placer gold and heavy minerals such as ilmenite, rutile, monazite, and some radioactive minerals in the Tertiary sediments of the peninsular part are also indicated by some workers (Khedkar, 1954).

Laterites

The laterites contribute to a large extent (roughly 50 per cent.) of the total rock outcrops found in this State. The distribution of laterite

and lateritic soil is limited to parts of the peninsular region of the State comprising the eastern part of Bankura, Burdwan, Birbhum, part of Murshidabad, south-western corner of Midnapur and parts of Purulia districts, altogether covering an area of 7,700 sq. km. (3,000 sq. miles).

Laterites are known to form by the sub-aerial weathering of almost all types of rocks in a monsoon climate with alternate dry and wet seasons. As such, these are fairly wide in their distribution, capping rock types of all ages from the Archaeans to the Tertiary grits found in this State. The laterites are partly primary in the sense that they could be traced to the parent rock from which they have been derived, partly detrital and the remaining are of doubtful origin, where they have been transported far from the source.

The primary laterites usually occur as hard consolidated blocks and show variegated colours and contain fragments of pebbles etc. Occasionally, they are of huge dimensions and of considerable thickness which sometimes ranges from 6 to 15 m. or more. The detrital laterites occur in loose concretions as gravels and pebbles, and are generally derived from weathered primary laterites and deposited far from their source of origin.

Laterites are known to have been formed in parts of India since the Getaceous till the sub-Recent times and is believed to be forming even to-day on the exposures of various rocks suitable for lateritisation, under optimum conditions.

Many of the laterite occurrences as in the eastern parts of the Bankura, Midnapur and Birbhum districts, show Tertiary formations below. In the Burdwan district, laterites are ubiquitous in the Raniganj coalfield, and isolated occurrences of laterites over undoubted Tertiaries have recently been observed. As such, these laterites can be considered to be younger in age, than the Tertiary possibly ranging up to Pleistocene of the Quaternary era. It is not unlikely that laterite occurrences which are hitherto grouped under the Older Alluvium in many places, may also have concealed the Tertiary formations below.

The laterites of this State are of the low level types. The level of the laterite country is generally 30 to 60 m. above the sea level which grades upwards into the alluvial flats, scarcely a few metres high (say for instance Calcutta is about 4.57 m. above m.s.l.). The comparatively high level laterites, as seen at present, suggest that there was a minor

differential uplift during the Tertiary, subsequent to the formation of the laterites. Laterites are generally underlain by lithomargic clays.

Alluvium

Laterites are usually succeeded by the next younger group of sediments of the Quaternary era. These alluvial sediments are found both in the extra-peninsular and peninsular regions of the State.

The deposition of the alluvial sediments commenced after the final upheaval of the Himalayas and continued all through since the Pleistocene times. Lithologically, the alluvial formations consist of massive beds of clay (either sandy or calcareous) corresponding to the silts and sands of the present day rivers. The alluvial deposits cover approximately four-fifths of the area of the State concealing the older rocks under variable thicknesses of sediments. These alluvial formations are classified into *Bhangar* or Older Alluvium and *Khadar* or Newer Alluvium. The Older Alluvium is coarse and generally of reddish colour containing abundant disseminations of calcareous and limonitic concretions. The Older Alluvium which generally occupies comparatively higher grounds, is known to occur in the Barind tracts of the Malda and Dinajpur districts and also in the Bankura, Midnapur and Purulia districts. The Older Alluvium probably is of Middle Pleistocene age.

The Pleistocene sediments occur in the *Bhabar* region of the foothills in the Darjeeling and Jalpaiguri districts, in the western parts of the State flanking the Rajmahal and Chotanagpur hills and the Barind areas of North Bengal. These are composed of sands, silts with some pebbles containing wood fragments, which show rolling effects imparted to them during transport by torrential currents. The *Bhabar* zone has a vertical thickness of less than 300 m. The Older Alluvium extends to a depth of 122 m. from the surface at Hijla (Chatterjee, 1949).

The Newer Alluvium or *Khadar* is mostly confined to present day channels and contains less calcareous matter. The Newer Alluvium is of sub-Recent to Recent age and gradually merges into the delta consisting of alternate beds of clay, silt, sand, marl, peat bed, lignite and some forest beds.

In and around Calcutta and also in Howrah and 24-Parganas, peat beds were encountered at depths ranging from 1.8—10.7 m. (6 to 35ft.). Peat beds are also reported from a river basin in the Kharagpur area in the Midnapur district.

The thickness of the Ganga alluvium is considered to be the greatest

in that portion of it lying between Delhi and Rajmahal hills. The fore-deep, south of the Himalayan range, also contains a considerable thickness of this alluvium. There are various estimates regarding the thickness of the Ganga alluvium. Oldham considered it as 4,572 m. (15,000 ft.) while Glennie estimated it as 1,980 m. (6,500 ft.) based on geodetic data. D. N. Wadia and J. B. Auden were of the opinion that Glennie's estimates should apply to the combined thickness of Tertiaries and alluvium.

The Ganga-Brahmaputra alluvium within the State has since been penetrated at certain places in course of exploration for groundwater and oil. These revealed a thickness of 610 m. in the portion south of the Himalayas, less than 300 m. in the Rajmahal gap area, 73 m. at Galsi, 210 m. at Jalangi, 333 m. in Burdwan and 610 to 914 m. in the Barasat-Madhyamgram area and probably in Calcutta as well. The sub-surface data collected suggest that the thickness of the alluvium increases towards the east and south-east. It was found to be several hundred metres at Bogra in East Pakistan capping the Gondwanas which were encountered at a depth of about 2,438 m.

In the river basins, in the western part of the State, the thickness of the alluvium was found to be appreciable ranging up to several scores of metres (Banerjee, 1960).

The data obtained during deep drilling by the Standard Vacuum Oil Company indicate at places, under variable thickness of the alluvium, the existence and extensions of all sub-divisions of the Tertiary formations, which were previously found as detached exposures in the eastern fringe of the western districts and in the southern fringe of the northern districts of West Bengal. The sedimentaries were found to be underlain by basic lava flows related to the late Jurassic to Lower Cretaceous period of vulcanicity. Thus, from the upper Mesozoic to Tertiary, the basin movements in the Bengal delta commenced with the formation of trap-wash rocks under continental, fresh water, lacustrine and lagoonal conditions. Several phases of marine transgression and regression have been suggested from the interpretation of the sub-surface data. The deposition continued till the Lower Cretaceous period until the downward movements resulted in marine incursions during the early Upper Cretaceous times. It is conceived that there had been subsequent periodic marine regressions, and this was followed again by a strong marine sedimentation early in the Middle Eocene to Upper Eocene times which were more widespread, and possibly covered the entire Bengal area. It is considered that there was again a widespread

marine regression when another cycle of marine sedimentation started during late Oligocene and early Miocene to the end of the Miocene time. Marine transgression and regression with uplifts were conspicuous in the Pliocene and Pleistocene times. These are considered to be related to the formation of the Tertiary folded belt of Tripura with the pronounced uplift of the Shillong massif and with the development of a less conspicuous (the Garo-Rajmahal) basement ridge.

Thus, the final configuration of the Bay of Bengal, formed as early as Jurassic time, was completed only in late Pleistocene to Recent times.

The beds in this basin are usually horizontal and/or are low dipping towards the east and south-east. The presence of several sets of faults affecting the structure of the basin and the disposition of the sedimentaries are also suggested by Recent sub-surface data.

The mineral assemblage of the silt from Calcutta is reported to contain ilmenite, hornblende, garnet, epidiorite, kyanite, tourmaline, staurolite and sillimanite, and differs from that of Assam alluvium in having sillimanite throughout.

The economic deposits within the Recent alluvium are gold (?), sand including the coastal dune sands, black sands containing magnetite, ilmenite, rutile, pottery and brick clays, other building materials including river sands, moulding sands, *kankar* and gravel and saline efflorescence.

Soils

In the higher slopes of the Darjeeling Himalayas, red and yellow podzolic soils have developed on the gneisses and schists, and humus podzols in the valley bottoms and other depressions. The hill-wash, that is, the alluvial fan debris (piedmont deposits) consisting of gravel and coarse sand occurs along the foot of the Darjeeling Himalayas. The soils formed on these materials are not well developed, and they are agriculturally useless. Tea bushes grow abundantly in this region.

The Older Alluvium and the metamorphic and gneissic rocks at places in the western part of the State, have been lateritised giving rise to red earths, lateritic soils, and laterites. In the Archaean terrain the soils are mostly residual. These are yellowish brown in colour, sandy and generally thin. The low ground in this terrain has a

sedentary sandy clay loam varying in thickness from 0.15 to 0.45 m. (one metre at places). All types of cultivation are naturally local in these low grounds. The soil erosion is very active in this region, and as a result, about 60 to 70 per cent. of the land has only thin cover of decomposed rocks and sub-soils left on it, and is of no use for agriculture (West, 1950, p. 183).

In the plains, most of the soils have been derived from alluvial deposits forming flood plains and deltas, and are azonal with little or no profile development. In most cases, they are loamy. Texturally, these may be divided into sands, loamy sands, sandy loams, river silts or silt loams, clay loams, and clays. Pure sands forming sand dunes occur mainly along the coast, loamy sands along the northern bank of the Ganga, sandy loams in the alluvial plains of the north, and silts or silt loams along the banks of the Tista and Bhagirathi-Hooghly rivers. Elsewhere in the plains, clay loam is the predominating type of soil. Clays with or without muck soils occur in swamps and alluvial lakes. Alluvial soils along the coast and especially in the Sunderbans area show white efflorescence of sodium chloride, as they are impregnated with this and other salts by tidal estuaries (Chatterjee, 1949, p. 14.).

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CHAPTER IV

HYDROGEOLOGY

Water for all purposes is derived from three principal sources namely :

(a) *Surface water*—rivers, streams and water sources and the impounded reservoirs and tanks.

(b) *Groundwater*—water which seeps underground and collects in favourable zones in the sub-stratum—extracted by means of dug wells and tubewells,

(c) *Springs*—form when the groundwater emerges intermittently at favourable points at the contact zones of suitably disposed permeable and impermeable beds.

The physiographical and geomorphological set up have a direct bearing on the hydrological conditions prevailing in any region. Thus, the State of West Bengal may be broadly divisible into three distinct hydrological zones. These zones have their peculiar characteristics in respect of hydrological conditions and water supply, in relation to the geomorphological set up and disposition of the various geological formations.

A. *Northern Zone* : (i) The hilly region of the Darjeeling and Jalpaiguri districts forming parts of the Eastern Himalaya.
(ii) The *Terai* and *Bhabar* region at the foot hills zone.

B. *Western Zone* : (i) The peneplaned Archaean terrain in the western part of the State.
(ii) The sedimentary region including the coalfields, the Tertiaries and the laterites in the western part of the State.

C. *Eastern Zone* : (i) The alluvial plains and
(ii) the coastal region.

Northern Zone

It comprises the districts of Darjeeling, Jalpaiguri and Cooch Behar. In the hilly regions of this zone, forming part of the eastern Himalayas, the rainfall is high, ranging from 250 to 500 cm. annually. Owing to the impervious nature of the rock and the rugged topography, the run-off in this area is high. The rivers

and streams are often in spate during the monsoon. The water supply in these areas is mainly derived from *jhoras*, rivers, streams and reservoirs and occasionally from springs.

In the alluvial stretch of this zone, besides resorting to the usual sources of surface water, ground-water is also tapped by means of dug wells and tubewells.

The Tertiary and the Gondwana sediments form the foothills zone, which is fringed by talus fans composed of rock fragments, gravels and soils supporting good forests. The *Terai* tract lying immediately below the Bhabar zone, is composed of gravel and soil forming a marshy tract with grass and thick jungle. Several saturated granular zones at depths ranging between [illegible] and 150 m. yielded 57,600 to 190,000 litres of water per hour during the recent exploratory drilling at Salbari (26°46′ : 88°22′), B[illegible]ajole (26°42′ : 88°14′) and Fatapukur (26°53′ : 88°3[illegible]′) in this region.

Western Zone

It constitutes the rocky parts of Burdwan, Birbhum, Bankura, Midnapur and Purulia districts. Portions of this zone comprising the western high land are located on the hard impervious crystalline rocks, while the rest is made up of the Gondwana sediments, the Tertiaries and the laterites.

Water supply in the crystalline tracts is mainly derived from surface water flowing in the rivers and streams or collected in reservoirs and tanks. The rivers and streams, which sometimes overflow their banks after heavy rains, are barely perennial. The majority of them retain only occasional shallow stagnant pools of water along their courses during the dry season. Where surface water is not readily available, the inhabitants resort to extraction of groundwater through dug wells. Dug wells are generally shallow, scarcely exceeding 15 m. (50 ft.) in depth. As there is no proper aquifer in the crystallines, these tap only localised water bodies collected in the cracks and crevices of the impervious rocks, and also from the upper weathered zones of the bed rock. Where the thickness of the soil mantle is considerable, the discharge from these wells is generally satisfactory. A majority of the shallow wells go dry or retain scanty water during the summer. As such, the area suffers from general scarcity of water.

In the rest of the rocky part of this zone which is covered

by formations other than impervious crystallines, the water supply is comparatively better. Besides the surface water resources, the dug wells tapping the aquifers of the younger sedimentary formations, are generally found to be successful. Wells sunk along the river and stream courses yield a copious supply of water. A few tubewells are working in Midnapur and Jhargram, but the quantity of water obtained from these is small. The aquifers are irregular and lens shaped.

Unlike the Archaean terrain, the sedimentary region including the coalfields and the Tertiary areas holds a better prospect for the development of groundwater by exploratory tubewells. The Tertiary and Pleistocene deposits in the districts of Birbhum, Burdwan, Bankura and Midnapur are mostly covered by a variable thickness of laterite which even envelopes some portions of the peneplaned and highly weathered gneissic terrain to the west. This laterite has generally clay beds at its base. In this region, the level of water rises to the maximum during the rains, but at the end of summer, it falls almost up to the top of the clay bed. The rise and fall in the level of groundwater is very sharp, and there is always a steady outward discharge from the centre of the high land outwards. Thus, a large volume of water in the laterite cappings is discharged. A similar behaviour is noticed in the case of detrital laterite also ; and the water is discharged more rapidly if the laterite mantle is sufficiently above the surrounding drainage.

Eastern Zone

It constitutes the alluvial plains and coastal regions comprising almost four-fifths of the total area of the State, and is fortunate in its resources of water.

In this region, groundwater plays an equal, if not greater, role over the surface water resources. Dug wells and tubewells, which are numerous, behave satisfactorily.

The first attempt to obtain artesian water in the State was made in Calcutta in 1804, and the first deep boring (147 m.) for it was made at Fort William, Calcutta in 1838. A considerable activity by the Agricultural Department, Government of Bengal, in sinking wells in search of sub-soil water was witnessed around 1909. Later, the Corporation of Calcutta, the Railways, the Calcutta Electric Supply Corporation, the Calcutta Port Authorities and other agencies did many borings in and around Calcutta and in

other parts of the State. These and other borings at Bally and Howrah bridge revealed a great deal of sub-surface data in the area. Intensive geohydrological investigations started since 1953 when the Government of India, in collaboration with the Technical Co-operation Mission of the U. S. A., undertook extensive test drilling for exploring groundwater resources of the country, there by delineating areas suitable for the development of ground-water for agriculture and other purposes. The Exploratory Tubewell Organisation was later set up under the Ministry of Food and Agriculture, Government of India.

The fluviatile deposits of the Ganga-Brahmaputra, forming the plains of Bengal, consist of lenticular beds of sand and gravel, and peat beds (Newer Alluvium). The Older Alluvium is rather dark coloured and generally rich in Kankar (calcareous nodules). The Older Alluvium forms slightly elevated terraces, generally above the flood level. Water is available in large quantities at comparatively shallow depths in North Bengal. In South Bengal, the meandering Hooghly, Ichamati and other rivers have left an unevenness the alluvial plains which controls hydrographic patterns. Groundwater in this area occurs in a very thick zone of saturation and is under water table condition at reasonable depths. These zones when tapped, yield copious supply of fresh water. Calcutta and its environs are situated on the low lying flood plains of the Hooghly river, and are underlain by widespread and thick alluvial deposits of Quaternary age. The quality of groundwater of this area varies very rapidly, both vertically and horizontally. The water is mildly alkaline (the maximum pH value recorded is 7.8) and quite hard. The deepest drilling made so far in Calcutta is 614 m. at the I. D. Hospitals, where the Upper Tertiaries are met with.

Alluvial soils along the coast and especially in the Sunderbans area show white efflorescences of sodium chloride and other salts. The water in the tidal estuaries is saline and is useless for domestic and other purposes. The zone of salinity extends from the coast and Midnapur to south of Calcutta including the whole of Sunderbans. Exploratory boreholes at Samudrapur (23°44′ : 87°03′) and other areas in the Sunderbans are being made to locate underground fresh water pockets.

Calcutta Water Supply : Calcutta's water supply is drawn from the Hooghly river at Palta, about 27 km. north of Calcutta. After being pumped into settling tanks, the water is filtered

before supply as potable water. The daily consumption is over 364 million litres (80 million gallons). Unfiltered water is pumped direct from the river and used for drainage, flushing etc. There are also a number of tubewells of varying depths operating in Calcutta and the suburbs. The groundwater level below Calcutta varies from 3.6 to 5.5 m. (12 to 18 ft.) from the surface. The sub-soil water being hygienically unfit is not generally used. A. L. Coulson (1940) comments that "for potable water, it is generally necessary to sink a tubewell to at least 91 m. (300 ft.), more usually to nearly 122 m. (400 ft.) and occasionally to 229 m. (750 ft.) or more." According to him, "50 per cent. of the local rainfall percolating into the soil is likely to add or replenish the hygienically unfit sub-soil water under Calcutta maintaining its normal position a few feet above mean sea level but has no material effect on the deeper zone of potable water. The deeper sub-soil water, in view of its generally slow and definitely southerly flow, has a distinct origin and is derived by percolation from the Ganga and Brahmaputra rivers over a hundred miles to the north, the percolation rate through the pores between the beds of the discontinuous sand beds being extremely slow at the rate of a mile or so a year".

Reservoirs or sub-surface storages of water are meant for irrigation, for generation of hydro-electricity and for general water supply. The Damodar Valley Corporation Project is one such ambitious scheme of West Bengal. The Kangsabati, Mor, Jaldhaka, Farakka and the proposed Ajoy and Subarnarekha projects are other important schemes.

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CHAPTER V

EARTHQUAKES

Many of the major Indian earthquakes that occurred during the 19th and 20th centuries had their epicentres in the north-eastern part of India as suggested by the following list :—

1. Bihar-Nepal earthquake of 26th August, 1933.
2. Assam earthquake of 10th July, 1869.
3. Bengal earthquake of 14th July, 1885.
4. Assam earthquake of 12th June, 1897.
5. Assam earthquake of 8th July, 1918.
6. North-Bihar earthquake of 15th January, 1934.
7. Tibet-Assam earthquake of 15th August, 1950.

The Assam earthquake of 1897 is considered to be the severest in Indian history. The Bihar-Nepal earthquake of 1934 was somewhat less severe while the Tibet-Assam earthquake of 1950 though extremly disastrous in parts of Assam, the actual epi-central region has not yet been fully investigated. All these earthquakes originated in the Indo-Ganga plain or in the montane regions at its peripheries. The northern and the eastern alluvial portions of the State of West Bengal being within this part, the State has naturally experienced the effects of these earthquakes though in varying intensity in different parts.

Thus, during the 1897 earthquake, the most disastrous effects were experienced in Cooch Bihar and Darjeeling districts, whereas the intensity was somewhat low in the south. In Cooch Behar which probably came within Isoseismal X (Mercalli Scale), the general effects were disastrous ; many buildings were ruined with the development of cracks and fissures. In the Darjeeling, Jalpaiguri, Malda, Murshidabad and Dinajpur districts, the intensity fell within Isoseismal IX, and the effects included complete or nearly complete ruination of some houses and serious cracks in many others, loss of lives in different parts of populous places, extensive fissuring in the alluvial ground and landslides in montane regions, whereas in Calcutta, which was within Isoseismal VIII, the shock was felt with a great alarm and it caused damage to some houses with considerable cracks in others. There was, however, no loss of life.

During the 1934 earthquake, the maximum intensity was equivalent to Isoseismal VIII in the Darjeeling district and between VII and VI in other parts of Bengal. The general effects of the intensity of Isoseismal VII, according to J. A. Dunn (1939), were "very strong, felt with general alarm and flight from house, sensible also out-of-doors; ringing of church bells, fall of chimney tops and tiles, cracks in numerous buildings, but generally slight, whereas those of Isoseismal VI are strong, felt by everyone indoors, and by many with alarm and flight into the open air; fall of objects in houses, fall of plaster with some cracks in badly built houses."

The great 1950 earthquake which so severely affected parts of Assam did not cause any perceptible damage to any part of West Bengal, although the shock was felt throughout.

The 1934 earthquake is believed to have been caused by a fracture of the substratum below the alluvium. Such fractures below the alluvium, within the limits of the State, are also not improbable. According to previous workers, the entire Ganga plains extending from North Bihar through North Bengal to Assam can be considered to be susceptible to earthquakes. In the rocky parts in the west, the isoseismals are not likely to exceed VIII. Hence it would be better to build houses with earthquake-proof designs specially in the montane regions and in the alluvial plain south of the Himalayas. For bigger structures like dams etc. in western parts of Bengal, provisions for an acceleration due to gravity amounting to about 1/10th *g* should be made in the designs.

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PART II

CHAPTER—VI

A REVIEW OF THE MINERAL RESOURCES AND MINERAL INDUSTRY IN WEST BENGAL.

Despite its comparatively limited area (approximately three per cent. of that of India), the State of West Bengal continues to retain the second position, since decades, in the value of mineral production of the country. Thus, of the West Bengal's share of 21.6 per cent. (Rs. 402.9 millions) in the total value of minerals (Rs. 1,867.8 millions) produced in India in 1962, coal accounted for 99 per cent., both in output and value (Rs. 401.41 millions) within the State *vis-a-vis* 72 per cent. of India's mineral production. The output of coal from 228 mines (1963) of the State works out to about 30 per cent. of the all-India coal production in the same year, and the percentage was more or less the same during the preceding year. The State's contribution to the overall mineral production of the country in the preceding years (1951-61) fluctuated between 21 and 22 per cent. while the all-India value of mineral production registered a steady and remarkable rise towards more than doubling the value by 1962 (Rs. 1,680 millions) from the level of 1951 (Rs. 852.4 millions). The index of mineral production rose to 146.1 during 1962 (Base 1951 = 100) for the entire country.

During 1951-1962, the value of mineral production in West Bengal showed a spectacular increase from Rs. 143 millions in 1951 to Rs. 406 millions in 1962. This can be attributed more to the rise in the price (particularly that of coal) than to the variety and rate of increase in the production.

With this background in the trend of the mineral industry, it becomes obvious that the mineral industry in the State since its very inception to its present stage, not only owes its growth and stability to coal, which is the principal mineral asset but also has a practically unlimited scope to thrive as a whole if the vast resources of coal are properly assessed, skilfully exploited and put to varied utilisation it rightly deserves through proper planning. Ancillary to this, the connect-

ed development of ceramic and refractory industries based mainly on the clay and other resources of this State will also contribute to the prosperity of the State.

The other mineral resources of this State, that have been assessed, are limited to a few minerals such as sea salt, fire-clay, china clay, limestone, dolomite, talc-steatite, moulding sand and building materials. Local occurrences of manganese-ore, tungsten-ore, copper-ore and mica are also reported. Other mineral occurrences of this State, *viz.*, gold, arsenic, iron, lead, graphite, sillimanite, bismuth, garnet, magnesium, molybdenite, silver, uranium, quartz, felspar, kyanite etc., appear only to hold an academic interest.

Apart from coal, the following minerals are also produced in small quanitities :—

(1) Salt, (2) Clay, (3) Limestone, (4) Dolomite
(5) Ochres, (6) Tungsten-ore, (7) Building Materials,
(8) Mica, (9) Manganese-ore and (10) Kyanite.

The known mineral occurrences in West Bengal are restricted to a limited area, located in the two northern districts, *viz.*, Darjeeling and Jalpaiguri and in five western districts. The eastern part of the State, being composed wholly of alluvial deposits, is not potential enough to contain metallic and non-metallic economic mineral deposits as in other districts. The potentialities of these districts to the east, (which contain concealed Tertiary formations below) in respect of oil and natural gas, however, yet remain to be fully assessed. Similarly, in certain areas, in the north and south, possibility exists for the extension of coalfields under the alluvium.

Coal and fire-clay are mainly localised in the Raniganj coalfield, in certain areas of Burdwan, Bankura and Purulia districts in the west and also in the Darjeeling district to the north, while good deposits of *china clay* are found in the Birbhum and Bankura districts with limited occurrences in the Midnapur, Burdwan and Darjeeling districts. Good deposits of *dolomite and limestone* are found in the Jalpaiguri and Darjeeling districts with limited occurrences in the Bankura and Purulia districts. *Potstone* and *refractory materials* including *talc-steatite* are found in the Darjeeling, Bankura and Midnapur districts. *Cherty quartzite* in the Bankura and Purulia districts may perhaps prove to be a good acid refractory material.

Moulding sands and *ochres* are found in the Burdwan and Birbhum districts and limited occurrences of *iron-ore and silica* are reported from the Burdwan district, while *tungsten-ore* (wolfram and scheelite), *lead*, *mica*, and *vermiculite* occur in the Bankura district. *Manganese-ores* are reported from the Midnapur district and *uranium-ores* are found in the Purulia district. Occurrences of doubtful potentiality such as copper-ores, silver, arsenic etc. are also reported from the Darjeeling district. *Building and construction materials* are fairly abundant in the five western districts and in the two northern districts as well.

The State's known reserves of coal, clay and dolomite are in appreciable quantities, and need proper development and manifold utilisation, while those of vermiculite and ochres are attractive enough for development of paint industry and so are also of potstones, for suitable utilisation. West Bengal's salt industry needs special encouragement. Occurrences of tungsten and copper-ores need special attention for immediate assessment of the potentiality. Recent findings of manganese-ore are a welcome addition and their utilisation in the manganese dioxide industry in particular deserves attention.

As a corollary to the naturally localised distribution of commercially significant mineral deposits in the State as also to the existence of port and transport facilities, the mineral-and metal-based industries are noted for their polarisation in and around Calcutta, in the 24 Parganas district, and also in the nearby regions of coalfield such as Durgapur (Burdwan district) and Kharagpur (Midnapur district).

This State contributes a share ranging from two to three per cent. (2.8 per cent. in 1956) between 1951 and 1961 in industrial production compared to the all-India average of one per cent., and in matters of employment mining accounts for one per cent. in the State as against 0.5 per cent. for the all-India basis. Although, the State's total income is only eight per cent. of that of India, the *per capita* income is higher (being Rs. 281) than that compared to Rs. 260 of India as a whole, but the rate of increase in the *per capita* income is rather low being only 0.49 per cent. per annum *vis-a-vis* the all-India rate of 3.5 per cent., indicating a low trend in investment.

The mineral industry gained momentum with the initiation and progress of the Five Year Plans. As recorded by the National Council of Applied and Economic Research in the course of

economic survey of West Bengal, an investment of Rs. 677 millions with 1.7 per cent. in industry *vis-a-vis* India's seven per cent. (four per cent.)* (excluding the State's share on the expenditure on D. V. C.) was made in the First Five Year Plan including Rs. 371 millions from the State's resources. This investment is reported to reflect 7.4 per cent. of the State's income in the five years (*vis-a-vis* India's 15 per cent.) income in the country's outlay. The total outlay, however, as reported by the Planning Commission, was Rs. 1,540 millions* in the First Five Year Plan.

In the Second Five Year Plan, the investment amounted to Rs.1,582 millions (Rs. 1,450 millions)* including Rs. 811 millions as the State's share and reflecting 16 per cent. of the State's income in five years (*vis-a-vis* India's investment of 35 per cent. of income for the same period). The industrial development in the State is given a five per cent. share *vis-a-vis* India's 18 per cent. (20 per cent.)* in the Second Five Year Plan (1956-61).

The Third Five Year Plan also envisages a definite increase in the total outlay to the order of Rs. 3,460 millions (Rs. 2,500 millions provisional)* in the State with industry being given a four per cent. share (*vis-a-vis* India's 20 per cent.)* in the total outlay, as reported in the Techno-Economic Survey of West Bengal. In the report of the Planning Commission, the State's resources were envisaged as Rs. 900 millions, subsequently revised as Rs. 1,330 millions, in respect of the outlay in the Third Plan.

This trend of investment undoubtedly reflects an all-round development within the State in the field of industry, including the mineral-based one's. An investment of about Rs. 1,260 millions is suggested for mining development alone within the State for the current decade, *i. e.,* 1961-1971 (*i. e.,* till the Fourth Plan period), out of an envisaged outlay of Rs.20,155 millions for the same period. This envisaged investment is anticipated to increase the *per capita* income in the State to Rs. 397 *i.e.,* 3.7 per cent. of the income, as compared to Rs. 364 (3.1 per cent.) *per capita* income of India as a whole. Of this total outlay, the public sector is estimated to share 62 per cent., remaining 38 per cent. by the private sector and this is envisaged to yield an additional net output of Rs. 7,461 millions by 1971 including 17 per cent. from the private sector.

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* Figures taken from the Techno-Economic Survey of West Bengal.
Figures in Parenthesis from Third Five Year Plan publication by the Planning Commission.

Metallurgical and metal-based and chemical (particularly coal-based) industries are anticipated to contribute most of the additional net output in the field of industries and the average rate of growth was worked out to be about 10. 9 per cent. per annum.

Of the total envisaged investment of Rs.1,260 millions (1961-71) mainly on the seven minerals of this State, the coal mining and development programme alone is alloted Rs. 1,256 millions (including Rs.45 millions for the establishment of a Coal Washery with a capacity of 2.24 million tonnes per annum) in the Raniganj coalfield towards reaching a total anticipated output of 53 to 56 million tonnes, accounting for the usual 30 per cent. share of the State in India's increased production, as envisaged by that period. This is followed by the proposed investment of Rs. 900,000 on fire clay mining, Rs. 700,000 in limestone mining, Rs. 600,000 each on china clay (mining and washing), manganese and wolfram, and Rs. 300,000 on soapstone mining during the period 1961-1971.

The details of the investment in mineral industry proposed in the State, their output and employment, as suggested by the National Council of Applied and Economic Research in course of Techno-Economic Survey, West Bengal, is reproduced in Table 3 below, for a ready reference together with the production statistics for these minerals during 1961 and 1962 for comparison:—

TABLE 3

Minerals	Total investment (1961-71)	Proposed employment	1971 Production envisaged annually (tonnes)	Production & Values	
				1961	1962
1	2	3	4	5	6
Coal (mining and development including Rs. 45 millions for a Coal Washing Plant with 2.2 million tonnes capacity per annum)	Rs. 1,256.6 millions	33,000	52,832,000	17.54 million tonnes (Rs. 357.4 millions)	19.08million (Rs. 401.4 millions).
Fire-clay	Rs. 900,000	1,200	304,800	21,265 tonnes (Rs. 168,000)	35,987 tonnes (Rs. 174,000)
Limestone (development & washing)	Rs. 700,000	300	101,600	8,118 tonnes (Rs. 51,000)	29,586 tonnes (Rs. 196,000)

1	2	3	4	5	6
China clay (mining & washing)	Rs. 600,000	400	101,600	47,976 tonnes (Rs. 337,000)	46,766 tonnes (Rs. 327,000)
Manganese	Rs. 600,000	2,000	50,800	27.4 tonnes (Rs. 1,000)	—
Wolfram (mining)	Rs. 600,000	700	3,048	9.18 tonnes (Rs. 35,000)	10.44 tonnes (Rs. 30,000)
Soapstone (mining)	Rs. 300,000	90	6,096		
	Rs. 1,260 millions	37,690	53,399,944		

In this process of planned development towards achievement of the anticipated targets outlined above, on the seven minerals in particular, the mineral industry in the State will require the following immediate measures: —

1) full assessment through systematic exploration of the entire coal resources in the old and new areas ;

(2) skilful exploitation of the coal resources as per requirement in the existing and envisaged production including power, gas and coal-based industries and the study towards removing the problems facing the coal industry ; marketing studies of coal (which so long had the principal utilisation in the Railways) in other growing industries and rational utilisation ;

(3) utilisation of the coal fines ;

(4) installation of a washery in the coalfield for proper utilisation of the caking coal resources and middlings in other industries ;

(5) installation of low and high temperature carbonisation plants, gassification plants and tar units, thermal power plants ;

(6) installation of a number of integrated coal-based chemical industries ;

(7) installation of synthetic oil plant, utilising the low grade coals. Possibility of its utilisation in the proportion of 7:1 (seven tons of coal to one ton of oil) have been investigated by the Geological Survey of India and Ondal area was indicated as a suitable site for the purpose ;

(8) regional and detailed assessment of the State's potentiality of the internal resources, including clay, (china clay and fire-clay),

limestone and dolomite, manganese-ore, talc and other refractory materials, mica, vermiculite, arsenic-ores and tungsten-ores. Tungsten-ores are utilised not only for manufacture of special steels but may be utilised also for growing a tungsten-carbide industry ;

(9) utilisation of the clay and other refractory materials particularly cherty quartzites through installation of additional units ;

(10) utilisation of blast furnace slag in producing slag cement ;

(11) possibility of making slag and rock wool industries should be explored ;

(12) utilisation of resources of vermiculite in paint industries ;

(13) full assessment of the eastern part of the State in respect of potentiality of natural gas and oil ;

(14) power resources (hydro-electric and thermal) need immediate development towards making available cheap power for expansion of the existing large-scale industries *viz.*, iron and steel and aluminium in the State as well as for fostering development of new ancillary engineering and other industries ;

(15) transport facilities, including water ways, railways and road ways, need development towards healthy growth of the industry throughout the State instead of at one place ;

(16) dispersal of the industries, particularly the new industries, through development of the transport system, increase of labour and other facilities and port facilities (Haldia port in addition to Calcutta) and building up of new townships will go a long way towards all round development of the State through mobilisation of her internal resources.

The planned implementation of this ambitious development programme through the suggested measures as outlined above, will foster the growth of coal and coal-based chemical industries besides promoting the much needed expansion of ceramic, glass, refractory and paint industries (which are hitherto under developed), and also the utilisation of the internal resources of the State.

The salt industry also deserves good impetus for expansion since this industry is only second to coal in respect of value of production (Rs. 636,000 in 1960 and Rs. 460,000 in 1961).

The reserve potentialities of minerals like wolfram and scheelite

(in the Bankura district) and manganese-ore (in the Midnapur district) are yet to be assessed through systematic exploration.

Apart from the coal-based industries, some of the large-scale mineral-based industries, which have prospects of expansion, utilising the available resources within the State, are the following :—

(1) *Cement industry*—Hitherto non-existent cement industry, utilising slag and limestone of the State, has a scope for installation at Durgapur with an annual capacity of 158,500 tonnes through an investment of Rs. 10 millions as recommended by the National Council of Applied and Economic Research.

(2) *Ceramic industry* :—The existing units draw their raw materials from other states in view of the unassessed and underdeveloped potential resources of clay deposits in this State. The largest of the existing ceramic units, the Bengal Potteries, is understood to have an expansion programme of 3,018 tonnes of high tension insulators annually.

It is necessary that through envisaged development of the potential clay deposits of the Birbhum and Bankura districts in particular, not only the requirements of the existing ceramic units in this State can be met with but the development would also reach an adequate level of production in order to foster the establishment of additional new units *viz.*, two white-ware units (each 1,524 tonnes annual capacity) and one sanitary-ware unit (500 tonnes annual capacity) near Suri in the Birbhum district ; and stone-ware unit (1,524 tonnes annual capacity) near Midnapur through a total anticipated investment of Rs. 155,000 on these four new units.

(3) *Refractory units* :—The existing six units manufacturing bricks, mortars and refractories have a total installed capacity of 142,240 tonnes per year. The construction of a new refractory plant near Durgapur, with an annual capacity of 12,190 tonnes has been suggested which would require a capital investment of Rs. 35 millions and will create employment for 3,500 persons. Attention should be drawn in this respect towards the occurrences of cherty quartzites in fairly large amounts in the Bankura and Purulia districts. An assessment of these deposits should be made in view of their possible use in the manufacture of silica bricks.

In 1956, out of 182 glass and ceramic factories in India, West Bengal had 46 units with a production rated at 32 per cent. of India's output. These industries marked an expansion by 64 per cent. in

terms of production, 58 per cent. in terms of net value and 47 per cent. in terms of employment. Considerable scope of growth exists in these industries.

Other existing large-scale mineral-based industries in the State, which are dependent on the import of raw materials from other States, include the following :—

Iron and steel Industries :—The State has two steel plants in the private sector (Indian Iron and Steel Company) at Kulti and Burnpur and another at Durgapur in the public sector. All these steel plants are located in the Burdwan district. The present production from these plants are :

IISCO., Kulti — 234,110 tonnes of pig iron during 1961

IISCO., Burnpur { 1,206,395 tonnes of pig iron during 1961-62
748,762 tonnes of steel during 1961-62
572,063 tonnes finished steel.

Durgapur Steel Plant—49,613 tonnes of finished steel in 1961.

Aluminium Industry :—The aluminium factory of the Aluminium, Corporation of India Ltd. at Jaykaynagar near Asansol, produces 5,080 tonnes of aluminium. The target of production of this plant by the end of the Third Plan period (1966) is 8,000 tonnes.

Indeed, the development of such large-scale metallurgical industries in the State, despite its dearth in many primary raw matarials such as iron-ores, aluminium-ores, metallurgical coal and manganese within its boundaries, is due to the following favourable factors as rightly assessed by the National Council of Applied and Economic Research during the Techno-Economic Survey of West Bengal.

(1) Its location particularly of its western districts, in the Damodar Valley development area which is rich in the relevant mineral deposits, and its proximity to the mineral rich regions in the south-eastern part of Bihar and north-easten part of Orissa;

(2) Existence of a first class port and of market facilities ;

(3) Availability of technical personnel business promoters and capital.

These steel industries have a scope of further expansion from their present stage to the target of four million tonnes (including additional 0·4 million tonnes in private sector by IISCO and 1·5 million tonnes in Durgapur by public sector) between 1961 and 1971, through an investment of Rs. 2,000 millions, *vis-a-vis* India's targets of 17. 5 million tonnes of steel by that period.

In respect of aluminium, the expansion envisaged in the factories of the State is 7,500 tonnes by 1966 and 10,000 tonnes per annum by 1971 (?) through an investment of Rs. 13 millions.

The development of power (Thermal and Hydel) projects in suitable lines, is absolutely essential in order to promote the growth of aluminium industries through provisioning of cheap power *vis-a-vis* its present high power tarriff in the State in comparision with the other states.

The metallurgical industries accounted for 18 per cent. of the productive capital and 20 per cent. of labour employed in the registered factories of West Bengal and contributed 21 per cent. of the net value aided by manufacture.

The ancillary metal-based engineering units of the State are the foremost (accounting for 40 per cent. of the net value in the country as a whole) and comprise mainly The Hindustan Cable Factory; The National Instrument Factory; The Chittaranjan Locomotive Factory; The Mining Equipment Factory (under construction) at Durgapur, apart from the big departmental workshops of the Railways, Port Commissioners, Public Works Department, and river valley authorities.

The small-scale factories represent 63.2 per cent. of the total factories in the State, and this proportion is more or less the same even for India as a whole. But the small scale mineral-based factories account for only two per cent. of the small scale factories of the State. These produce bricks and tiles, dressed and crushed stones, petroleum and coal products, glass products etc.

Coal-based Chemical Industries.—Chemical industries in the State, which account for nine per cent. of the State's capital, attribute the third place to the State of West Bengal in respect of employment, productive capital and in the net value of output. There is a considerable scope for developing coal-based thermal power and chemical industries for the construction of high and low temperature coal carbonisation plants with tar and distillation units, synthetic oil plants, plastic, wood preservative and resin manufacturing plants from benzene besides a production of napthalene, benzol, creosote oil and also for the manufac ture of carbon black and of anthracene oil. The wide range of coal-based industries need early establishment and development, apart from utilising bleudable coal after necessary washing for the metallurgical industries.

Power resources of this State need development through installation of thermal power grids and expansion of hydro-electric power projects.

TABLE 4.—*Production figures of principal minerals in West Bengal vis-a-vis the all-India production during 1951-62.*

Name of the mineral	Unit of quantity	1951				1952			
		West Bengal		India		West Bengal		India	
		Quantity	Value in Rupees '000	Quantity	Value in Rupees '000	Quantity	Value in Rupees '000	Quantity	Value in Rupees '000
1	2	3	4	5	6	7	8	9	10
Coal	Million tonnes	9.804	142,609	34.98	504,811	10.51	154,747	36.88	536,235
Fire-clay	'000 tonnes	36.723	232	114.364	800	28.794	189	120.903	936
China clay	'000 tonnes	—	—	70.104	1,856	189 tonnes	4	87.376	1,865
Limestone	Tonnes	—	—	—	—	—	—	—	—
Ochre	Tonnes	—	—	11,473	134	—	—	17,882	305
Wolfram	Tonnes	—	—	14.2	149	—	—	10.16	150
Salt	Tonnes	—	—	—	—	NA	NA	—	—

1	2	1953 3	1953 4	1953 5	1953 6	1954 7	1954 8	1954 9	1954 10
Coal	Million tonnes	10.39	152,263	36.56	527,677	10.77	157,390	37.47	539,093
Fire-clay	'000 tonnes	28.794	1,182	84.95	628	26.585	137	94.126	770
China clay	'000 tonnes	142	3	95.504	1,982	—	—	148.336	2,520
Limestone	Tonnes	—	—	—	—	—	—	—	—
Ochre	000 tonnes'	111	—	60.585	281	111	—	76.714	347
Wolfram	Tonnes	NA	NA	15.2	180	NA	NA	—	—
Salt	Tonnes	6,836	297	3,176,016	58,308	4,483	270	2,557,272	42,564

Name of the mineral	Unit of quantity	1955 West Bengal Quantity	1955 West Bengal Value in Rupees '000	1955 India Quantity	1955 India Value in Rupees '000	1956 West Bengal Quantity	1956 West Bengal Value in Rupees '000	1956 India Quantity	1956 India Value in Rupees '000
1	2	3	4	5	6	7	8	9	10
Coal	million tonnes	11.52	167,578	38.84	560,331	11.46	188,665	39.91	630,793
Fireclay	'000 tonnes	15,049	76	88,884	694	36,592	224	141,224	1,149
China clay	'000 tonnes	—	—	118,372	—	—	—	1,575,816	2,129
Limestone	'000 tonnes	—	—	—	—	0.91	16	8,044	29,873
Ochre	Tonnes	—	—	16,480	271	410	6	12,814	270
Wolfram	Tonnes	—	—	12.2	96	1.52	9	1.52	9
Salt	Tonnes	5,903	292	2,979,928	48,700	6,017	241	3,292,945	51,283

1	2	1957 3	1957 4	1957 5	1957 6	1958 7	1958 8	1958 9	1958 10
Coal	million tonnes	11.[illegible]	257,537	44,136	813,991	14.47	284,897	46,056	887,307
Fireclay	'000 tonnes	41,594	209	166	1,264	20.24	—	195	1,688
China clay	'000 tonnes	—	—	183	2,281	—	—	185	2,448
Limestone	'000 tonnes	26,541	81	9,571	34,353	6,304	3	10,533	—
Ochre	Tonnes	172	3	15,316	336	184	—	20,407	401
Wolfram	Tonnes	—	—	—	—	—	—	—	—
Salt	Tonnes	9,182	709	3,669,931	74,375	8,471	361	4,234,842	84,583

Name of the mineral	Unit of quantity	1959				1960			
		West Bengal		India		West Bengal		India	
		Quantity	Value in Rupees '000	Quantity	Value in Rupees '000	Quantity	Value in Rupees '000	Quantity	Value in Rupees '000
1	2	3	4	5	6	7	8	9	10
Coal	million tonnes	15.20	303,350	47.80	948,194	16.47	339,654	52.59	1,088,447
Fire-clay	'000 tonnes	20.843	91	218	1,596	20.983	111	258	2,165
China clay	'000 tonnes	1.96	19	277	3,666	39.837	141	353	4,892
Limestone	'000 tonnes	4,881	26	10,831	45,723	2,811	21	12,728	56,239
Ochre	Tonnes	1,087	56	21,190	465	618	15	20,400	382
Salt	Tonnes	7,688	308	3,177,647	59,300	10,450	636	3,435,677	66,900

		1961				1962			
1	2	3	4	5	6	7	8	9	10
Coal	million tonnes	17.256	357,421	56.065	1,171.94 millions	18.781	401,415	61.34	1,337,680
Fire-clay	'000 tonnes	20.928	108	270	2,307	35.424	174	337	2,886
China clay	'000 tonnes	47.218	337	371	4,408	46.026	327	384	4,529
Limestone	Tonnes	7,988	51	14.35 millions	67,088	29,939	196	16.318 millions	85,100
Ochre	Tonnes	466	8	19,248	348	308	5	15,350	303
Salt	Tonnes	6,100	460	3.46 millions	76,407	7,300	650	3.849 millions	94,900

Note : Mineral production figures from 1951 to 1958 : Taken from Techno-Economic Survey of West Bengal, By *National Council of Applied and Economic Research.*

Mineral production figures from 1959 to 1962 : Taken from Indian Minerals Year Book—1960, and Statistical Summary of Mineral Production of India—Dec., '62, 63 ; By *Indian Bureau of Mines.*

GROUP—I : OCCURRENCES OF MINERALS & MATERIALS OF KNOWN ECONOMIC IMPORTANCE

CHAPTER—VII

ABRASIVES

Artificial abrasives are fast replacing natural abrasives like daimond, corundum, emery, garnet, felspar, silica etc. but still their use as abrasives will continue so long as they are available cheaply.

The natural abrasives are classed into 'high grade natural abrasives', and 'siliceous abrasives'.

The high grade natural abrasives include the principal minerals like diamond, corundum, emery and garnet. West Bengal is not very rich in these abrasives excepting in corundum, which is found near Salbani (23°04' : 86°17') and Paharpur (23°23' : 86°47') in the Purulia district (see Chapter XXVI), and garnet, found along streams which traverse the mica-schist country in the north-western part of Midnapur, western part of Bankura and southern part of Purulia districts. But the quantity available from these sources is not known. Garnet is also found in a few other places in Bankura and Darjeeling districts. Dunn (1941) is of the opinion that the stream garnets of Bankura, Midnapur and Purulia districts are suitable for abrasive purposes.

The siliceous abrasives comprise the various forms of free silica, quartz, sand, sandstones, quartzites, flint, chert, tripoli, diatomite, silt, siliceous shales and clays, siliceous limestones, pumice, volcanic dust, rotten stone, felspars and granites.

Sand is used for cutting and polishing. Either river sands or friable sandstones may be used for this purpose. In West Bengal, plenty of river sands are available (Banerjee, S. 1960). The coarser portions of these sands need to be further crushed. Beds of friable sandstones might be found from within the vast deposits of Gondwana and Tertiary sandstones in the State (see Chapter XXII). Sands are also used for the manufacture of sandpapers. For this purpose, crushed and graded quartz, either from river sands or from quartz veins,

is suitable. Quartz veins are found in plenty in the Archaean tract of the State. As regards these raw materials, the State has good reserves.

Pumice, volcanic dust, tripoli, diatomite, china clay, chalk, lime, talc and ground felspars are the milder abrasives used generally in the powdered form for putting a finishing surface on wood or metal. So far it is known that pumice, volcanic dust, tripoli, diatomite, and chalk are not available in West Bengal. The State's resources of china clay, lime, talc and felspar have been incorporated in subsequent relevant sections.

Fine-grained and even-textured sandstones are used as grindstones, sharpening hones and millstones. Quartzites may also be used as millstones and sharpening hones provided they are fine-grained. Quartzites of this quality may be found in the Archaean rocks. Granite and trap rocks are sometimes used for millstones. The fine-grained Chotanagpur granites and the Rajmahal traps, dolerite dykes and lava flows may be utilised for this purpose.

Cherts, fine dense quartzites or pebbles of flint are used in mills for grinding limestone, cement, ores, clays, paint, etc., although at present these are being largely replaced by steel balls. But such pebbles are still being used where contamination with iron must be avoided as in pottery works. Flints and cherts may be found in the Rajmahal traps. A number of occurrences of cherty quartz have been reported from the Bankura district within latitudes 22°49′ and 22°58′ and longitudes 86°53′ and 87°00′ (Hunday, 1952) (see Chapter XXII). Beds of impure chert are also found in the Nimdih (23°00′ : 86°10′) area in the Purulia district.

Silicon carbide (carborundum), fused alumina (alundum), and boron carbide (norbide) are arificial abrasives imported into India. The manufacture of artificial abrasives depends on the availability of cheap electric power and the proximity to the source of raw materials. Both these conditions are likely to be fulfilled in the Damodar Valley area for establishing a plant for the manufacture artificial abrasives, and these materials will find a ready market in the industrial area in and around Calcutta.

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CHAPTER—VIII

BUILDING MATERIALS

The resources of different varieties of rocks which are used for construction and for civil engineering purposes are adequate in West Bengal. These materials range from alluvial clays for brick making, sands for mortar and cement-concrete, gravels for road metal, concrete and railway ballast, limestone for lime and cement, to various types of building, paving and ornamental stones. In general, the production of building materials in West Bengal is of local importance. The adjacent state of Bihar possesses more resources of these materials, and a certain amount of these find their way into this State. Expansion of trade in the building materials in this State is certain to continue as new schemes for different civil engineering constructions are forthcoming under the various Five Year Plans.

Building Clays

The material is of widespread occurrence, and enormous quantities of it are available from the alluvial tracts of the State for the manufacture of bricks, tiles, and common potteries. Ordinary clays are also used in cement manufacture. They vary widely in quality and suitability from place to place giving rise to finished products of different colour, porosity and strength. In general, the greater the plasticity of the clay the better is the quality of the bricks. The poor quality of many bricks is due to sandy nature of many clays used for this purpose.

River silts or silt loams and clay loams are also suitable for the manufacture of household bricks, tiles and other common potteries. Many brick fields are located alongside the rivers Hooghly and Damodar. Clays with or without much soil occurring in swamps and alluvial lakes are not suitable for these purposes.

In West Bengal, there is enough scope for research on the suitability of various types of clays for the manufacture of bricks and tiles. During 1956-57, the Central Building Research Institute carried out a survey of the brick industry in India, and the National Building Organisation under the then Union

Ministry of Works, Housing and Supply endeavoured to improve and modernise this industry.

Building Stones

Granite and granite gneiss :—Large quantities of hard, compact and resistant material like granite and granite gneiss are widely distributed in the Archaean tracts of the State. Fine to medium-grained Chotanagpur granite and granite gneiss, and some granite bodies like Kuilapal granite are suitable for these purposes. These rocks are difficult to work, and are used mostly as a road metal. The granitic rocks occurring towards the northern portion of the Bankura district are quite suitable for road metal and railway ballast. In the Birbhum district, granitic rocks are quarried near Panchra (23°46′:87°20′) and Dubrajpur (23°48′:87°22′). These are also available near Ranibahal (24°06′ : 87°20′), Adarpur (24°01′ : 87°31′), and from nearby places like Kushkbaspur, Haridaspur, Chak Mukunda, Chuaruli and Kurabali (Dutta, 1946). These are suitable for building purposes. Some of these rocks have fairly developed joints which facilitate quarrying. Granites and gneisses (Darjeeling Gneiss) occur in a wide area to the north of Kurseong (26°53′:88°17′) in the Darjeeling district. Granitic rocks (Lingtse granite) also occur near Kalimpong (27°04′:88°28′) and north of it, continuing into Sikkim. The Darjeeling gneiss is readily split into blocks of convenient size and is used for rubble masonry. These well jointed and fairly hard gneisses from the Sadar and Kalimpong sub-divisions can be used for road metal, railway ballast and in concrete aggregate. Large number of gneiss and granite boulders could also be collected from various hill streams and used for these purposes. Granitic rocks would undoubtedly form pleasing building stones and some of the curiously banded and figured granite gneisses could be used even for ornamental purposes.

Sandstones and quartzites :—Coarse sandstones of Upper Panchet, hard and massive sandstone bands of Lower Panchet and sandstones of the Raniganj series could be used for building purposes. A few temples and buildings in the area are built with these stones. Tests have proved that the Lower Panchet sandstones are more or less as hard as pure Portland cement (Roy, 1938). The sandstones are fine-grained, take good polish and can be chiselled into any shape. A considerable deposit of flagstone occurs

in the Upper Panchet formation. Good exposures of such rocks are found near Ranimahal on the Girijor in the Panchet Hill (.2,110 peak, 23°37′ ; 86°46′). The slabs are quite hard and durable, and can be easily sized bacause of good cleavage and lamination. The hard red massive conglomeratic bands in the Upper Panchet sandstone are suitable for railway ballast and road metal. These are available in large quantities. Talus deposits consisting of blocks of Panchet sandstones could also be used for such purposes. Large quantities of Panchet sandstones are also available from the Biharinath Parbat (.1483 ; 23°35 : 86°56′) and Gorangi hill (.953 ; 23°34′:86°52′), The sandstones of the Damuda series in the Raniganj coalfield yield good building material. The hard sandstone bands in the Raniganj series, the calcareous sandstones in the lower portion of the Talchir series, and the beds at the top of the lower Damudas (Blanford, 1863, p. 195) are good examples. Coarse Barakar sandstones have been quarried at Barakar (23°45′ : 86°52′) for despatch to Calcutta (Ball, 1881, p. 110), but they are incapable of withstanding great pressure. Some of the Barakar sandstones are suitable for making millstones and abrasive stones. The temples by the side of Barkar river are made up of these sandstones. Barakar sandstones at places may be a good source of quartz sand if the impurities are small or could be removed easily. Lower Gondwana sandstones are also available at the foothills of the Darjeeling Himalaya.

Fine-grained yellowish sandstones, coarse pebbly sandstones, ferruginous gritty sandstones and conglomerates of Tertiary age occur near Banskanali (22°58′ : 87°01′), Madanmohanpur (23°10′: 87°10′), Dunduria (23°00′:87°10′), Mukundapur (23°14′ : 87°11′) and Jhari (22°49′ : 86°51′) in the Bankura district (Krishnan, 1958). The fine-grained sandstones may be used for building purposes and the pebbles for concrete aggregates. These littoral shelf deposits are about 46 to 76 m. thick. Sandstones, conglomerates and pebbles of Tertiary age also occur in the districts of Birbhum, Burdwan and Midnapur. Some of the harder sandstones of the Tertiary beds at the foothills of the Darjeeling Himalaya would be good freestones, but they would require a careful selection (La Touche, 1918, p.30).

Sandstones and sandstone-quartzites of the Iron-Ore Series occur as high ridges near Bhandari (22°51′:86°32′) in the southern part of the Purulia district, and near Dhangikusum (22°35′ : 86°35′) in the

north-western part of the Midnapur district. These are usually of light grey or pale buff colour with pleasing appearance. Some of them have slightly greenish tint and are easily worked. The harder stones are capable of to king a good polish, but they are generally used rough-dressed. Slabs from the quartzite and hornblende schist bands occurring at Barabazar (23°02' : 86°22'), Layadih (23°10':86°20') and Japangdih (23°10' : 86°20') areas in the Purulia district are locally used for building purposes.

The quartzites of Susunia hill (.1,442 ; 23°24' : 87°00') in the Bankura district were quarried extensively at one time (Ball, 1881, p.110). These were used in Calcutta for paving, and as copings and curb stones. These are of excellent quality comparing favourably with the Chunar stones of Bihar as regards the absorption of moisture. Large quantities of felspathic quartzite are available from the band which is about 2.4 km. in length and about 1.2 km. in width. The villagers use this stone as potstone carving out bowls etc. The well developed joints in this felspathic quartzite facilitate its dressing into various shapes. These may be also used as paving stones. Fairly numerous relict hillocks of resistant quartzite bands within schists and gneisses are reported to occur to the south of Kama (22°53' : 86°44'), west of Kubasol 23°02' : 86°01'), west of Madhupur (23°02' : 86°48'), and near Bagjabra (23°02':86°51'), Makrara (23°00' : 86°51') and Diktor (23°03' : 85°46') in the Bankura district. The quartzite hillocks within latitudes 22°51' and 22°54', longitudes 86°45' and 86°55' in the Bankura district include Banmi Pahar, Bhuta dungri and Balka dungri deposits.

Hard banded quartzite is worked for road metals at Gidda Pahar near Kurseong (26°53' : 88°17') in the Darjeeling district. According to A.M.N. Ghosh (1945), the only suitable road metals available between Kurseong and Tindharia are the quartzites and the biotite-quartz-granulites. Both of these could be worked for many years. Dey (1949, p. 260) found exposures of these rocks on hill sides along the Darjeeling-Siliguri road between mile-stones 22 and 23. Hard white quartzites are also worked near the seventh mile-stone on the Ghum-Peshok road (Gee, 1940). Boulders of quartzites and other hard rocks are abundantly found in the beds of the hill streams and in the hill-wash in the foothills zone (West, 1950, p. 271).

Laterite:—This cheap building material occurs abundantly in the western districts of West Bengal. It is easily quarried and worked.

Slate :—Good deposits of slates are not found within the State. Slates occurring within the Archean sedimentary rocks are usually too soft and brittle to be of any value for building purposes. Coarse slates are obtainable from the Daling series in the Darjeeling and Jalpaiguri districts, but they are of small size and too brittle to be easily trimmed (La Touche, 1918, p. 30). Slabs of schists, phyllites and flaggy sandstones are used locally.

Trap :—Some old temples and forts were built of Rajmahal trap rocks occurring in the vicinity of Rajmahal hills, but their dark grey colour is not suited for modern architecture. Large quantities of trap rocks from these hills are used in West Bengal and Bihar as road metals and as aggregates for concrete. The quarries are located to the west of Rampur Hat at Naihati, Murai and Rajgram railway stations within the Birbhum district and to the west of Pakur and Rajmahal. At Pakur, these are quarried extensively and sent to Calcutta for sale.

Ornamental Stones

Banded quartzites :—These rocks occur within the Iron-ore series in southern Purulia and in the western and north-western parts of Bankura and Midnapur districts. The best of these rocks are the banded hematite-quartzites. They are extremely hard, take good polish and provide an unusual and striking ornamental stone, particularly when thin alternating layers of dark, pale red and white colours are finely banded and delicately contorted into close folds.

Granite-gneiss :—Some of the Chotanagpur granite gneisses could be used for ornamental purposes, such as for wall-panelling, stairways, archives and lintels. They also take good polish.

Marble :—Lenses and bands of crystalline limestone and marble are found near Jhalda (23°22′ : 85°59′) and Panchet Hill (23°37′ : 86°46′) in the Purulia district, and near Guniada hillock (208. m.) and Harirampur (23°08′ : 86°45′) in the Bankura district. Dolomites and dolomitic marbles occur in the Buxa Duars area of the Jalpaiguri district (see also Chapter on Limestone & Dolomite). Occasional patches of pure marble might be found within these occurrences, and could be used for ornamental work or even for statuary.

Rose quartz :—Translucent quartz with its colour ranging from pale pink to rose red is found in the mica pegmatites occurring within the

Archaean terrain of the State. It takes a most pleasing appearance on polishing and would be suitable for small panels or carved ornaments.

Serpentine :—Serpentine rocks associated with the ultra-basic ingeous rocks in the Archaean terrain of the State are suitable for ornamental purposes.

Soapstone :—Soapstones occur at several places in the Purulia, Bankura and Darjeeling districts (See also relevant Chapter) and have been quarried for use as houschold utensils (when it is called 'potstone'). They are grey are greyish green in colour, pleasantly figured and can be easily carved and polished. They are also used extensively for ornamental purposes. The numerous occurrences of talcose chlorite schists and talc-schists in the Bankura and Jalpaiguri districts are suitable for use as potstones. These are locally used for carving out bowls, pots and dishes of various designs. The talc-schists from the Buxa series are reported to be suitable for use as inner refractory linings in the kilns. Theso are also stated to be used with oil spray to stop mosquito breeding in the Duars area in the Jalpaiguri district. In the Bankura district, it is supporting small scale cottage industries at Matgoda (22°46' : 86°35'), Maula (22°50' : 86°46'), Panchpathar (22°56' : 86°57'), Kuldiha (22°47' : 86°54') and Ghoratupa (22°45' : 86°55').

Secondary silica such as agate and chalcedony, from the Rajmahal trap area, may also be used as semi- precious stones.

Lime and Cement

Occurrences of limestone, dolomite, calcareous tufa and *Kankar* in West Bengal are described in a separate chapter. Limestone is used in the manufacture of lime and cement which are required essentially in the building industry. There is no cement factory in West Bengal. A Slag Cement Factory at Durgapur has been proposed for construction.

Recently, the State Government and the Geological Survey of India have explored the possibilites of setting up of a cement factory either near Jhalda in the Purulia district or near Jalpaiguri utilising the nearby limestone occurrences. Good quantities of lime could be obtained from the dolomites of the Buxa series. Lime is also derived from beds of calcareous tufa (La Touche, 1918, p. 30). Another source of lime is *Kankar* (locally known as *ghooting* or *ghusik*) concretions which appear seasonally in the greyish clayey alluvial soil. *Kankar* is

formed by the segregation of calcareous materials into irregular lumps. This contains argillaceous impurities whose proportion in many cases is such that on burning it produces almost a hydraulic lime or *natural cement*.

Road Metals

The medium and fine-grained basic igneous rocks which have not suffered weathering or decomposition are the most suitable materials for roads carrying heavy traffic. These include the Rajmahal traps, dolerite dykes (particularly useful in the coalfields), epidiorites, hornblendic and pyroxenic rocks, and pyroxene granulites etc. The meta-dolerites and amphibolites near Barabazar (23°02′ : 86°22′), the basic dykes near Layadih (23°10′ : 86°20′) and Japangdih (23°10′ : 86°20′) in the Purulia district and the pyroxenic gneiss and pyroxene granulites in the area under Saltora P. S., Bankura district are good examples of such rocks suitable for road metals. M. S. Venkatram (1944, p. 525) selected medium-grained grey gneiss, epidiorite and hornblende schist for quarrying road metals in Jhalda (23°22′ : 85°59′), Balarampur (23°06′ : 86°13′) and in Banduan (22°52′ : 86°30′) area in the Purulia district.

The hard, dense and medium-grained quartzites, quartz-tourmaline veins, quartz veins, granulites, granites, granite gneisses and anorthosite rocks are suitable for road metals, railway ballast and concrete aggregates.

The hard fresh rocks should be used after rejecting the upper weathered and decomposed surface. The quartzites which have recrystallised to a coarse rock of sugary texture tend to break up under heavy traffic and wear away rapidly. The hornblendic granites are more suitable than those containing abundant mica. Coarse, porphyritic granites should be avoided, as the large felspar crystals when under load break up rapidly along the cleavages. In north Bengal, the hard dolomitic rocks could be used for these purposes. For roads carrying light traffic, gravels could be used. Laterites also make a good road surface.

Ballast

The same materials, such as trap, dolerite, quartzite etc., which are used for road construction, are also suitable for railway ballast.

These are also suitable for aggregate in concrete mixes. The basal Tertiary gravels of Midnapur, Bankura, Burdwan and Birbhum districts are also suitable for these purposes. These gravels are quarried near Dhalbhumgarh in Bihar, close to the West Bengal border, and are used as ballast along the permanent way of the S. E. Railway. These gravels also provided the aggregate in the concrete for the pier foundation of the Howrah bridge. Sometimes slags are also used in concrete aggregates. The ancient copper slags at Roam (22°38':86°24') near Rakha Mines in Bihar were used in concrete for the construction of the monoliths at King George's Dock in Calcutta. Similar slags from the Steel Plants in the State may be tested to find their suitability for these purposes.

Cement Concrete Aggregates

Tough and hard *rocks which can yield 1.3 cm.* (½″) *to 1.95 cm.* (¾″) pieces with a rough uneven surface and jagged edges are said to be the most suitable for use as aggregates in concrete. Chips crushed from basalts, dolerites, fine-grained granites and gneisses, granulites, quartzites, sized gravels and slags may be used as aggregates.

Sands and Gravels

The river sands of West Bengal are sufficiently clean at many places and suitable for use in plaster, mortar or concrete (see also relevant Chapter). Besides the river sands, good quality sands are also available under a variable thickness of soil at Mogra, Durgapur, Bally, Barrackpore and other places in Hooghly, 24 Parganas and Burdwan districts of West Bengal where from the bulk supply of sands are received in Calcutta and surrounding industrial areas for various constructional purposes. A reserve of about 0.23 million cu. m. (eight million cu. ft.) of sand conforming to fine aggregate Zone 11 of B.S.S. 882 and 1201 of 1954, required by the Durgapur Steel Project for constructional purposes, has been located in a part of the Kunur *nadi*, and in Raturia (23°30′:87°17′) and Arjunpur-Angadpur (23°31′ : 87°16′) areas within a radius of 19 km. around Durgapur (23°29′ : 87°18′) (Roy, 1962). Sands of Damodar and Ajoy rivers within the Raniganj coalfield are in great demand in recent times for stowing purposes in the collieries. S Banerjee (1960) has given a conservative estimate of about 1,091 million tonnes of river sands available from these two rivers included within the Raniganj coalfield. Enormous

quantities of sand are also available from the rivers of north Bengal. The Bhabar sands at the foot hills of the Himalaya are coarse-grained and unsorted. White and slightly yellow sands of the Ganga in the Murshidabad and Malda districts are fine-grained and sufficiently clean at places to be used for building purposes.

Large deposits of Tertiary gravel and pebbles occur at Kamalpur (23°36′ : 87°18′), Oariya (23°38′ : 87°75′), Ukhra (23°38′ : 87°15′) and places between Ondal and Durgapur in the Burdwan district, and near Gidni (22°28′: 86°50′) in the Midnapur district. The Gidni deposit extends into Dhalbhumgarh (22°31′ : 86°33′) and neighbouring areas of the Singbhum district in Bihar. The material is quarried extensively for various purposes. Deposits of Tertiary gravels and pebbles were also located in Barjora in the Bankura district. Suitable size-grades of these materials may also be used for shrouding tubewells. Bars and terraces of sand gravels occur in almost all the river and stream courses, particularly on flood plains, and at large bends and tributary confluences. Abundant supplies of gravel could be had from the Tertiary gravel, pebble beds and conglomerates and also from the *nala* beds in the foothills zone of the Himalayas in north Bengal.

Statistics

The statistics of production of the building materials as such from the State of West Bengal are not available. Some figures published in the Records of the Geological Survey of India until 1954 are given below:-

Year	*Tonnes*	*Value in Rs.*
1951	63,907	208,670
1952	41,637	158,646
1954	40,342	90,157

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CHAPTER IX

CARBONACEOUS MATERIALS

Coal

Coal is the key mineral of West Bengal and contributes about 99 per cent. of the State's mineral industry both in terms of value and production. This assures the retention of the second position of this small State in the overall mineral production of the country besides maintaining its contribution of about 30 per cent. of the coal production in this country.

In fact, the entire future prospect of the mineral industry in this State will continue to be hinged on coal, and the scale of expansion and utilisation of her vast and vital coal resources is still to attain a satisfactory level, in relation to the scope of utilisation.

The occurrences of coal in the Raniganj area and in certain parts of the Darjeeling district were known from an ancient time, and certain amount of it from the Raniganj field was used in Calcutta during the latter part of the eighteenth century. Mining of coal in the Raniganj coalfield had started as early as 1774.

Coal is, in fact, a sedimentary rock mainly of vegetable origin which accummulated in lakes, swamps, rivers and coastal lagoons and had undergone decomposition and physico-chemical changes under confined pressure and temperature conditions for ages. Based on the degree of change it has undergone, coal has been grouped as peat, (*i.e.* less altered vegetable matter), brown coal and lignite, different types of bituminous coal and anthracite. Graphite is practically pure carbon lying at the extreme end of vegetable transformation. In coal, the carbon is present as 'fixed carbon' and 'volatile matter' the ratio of which, called 'fuel ratio', is the main factor in determining the rank of coal. The volatile matter causes ready ignition and burns in the form of a gas, but too much of it gives a long and smoky flame and imparts poor storing qualities. The fixed carbon is the lasting and steady source of heat, producing a short, smokeless and hot flame. Sulphur, in the form of marcasite or pyrite, is an injurious impurity commonly present in most coals, and more than 1.5 per cent. of it makes the coal unsuitable for making gas or coke.

Coal may be '*in situ*' or of 'drift' origin. Indian coals are mostly of drift origin. In the peninsular area, coal belongs to the Gondwana Group (Upper Carboniferous to Lower Cretaceous in age), while in the extra-peninsular area, there are some deposits of coal belonging to the Tertiary age. The coal seams show cycles of deposition with the carbonaceous shale, sandstones and shales in tectonic troughs with faulted boundaries arranged along linear zones. The magnitude of the faults on the two major sides is generally unequal. In the Gondwana belt of the Damodar Valley, the faults run east-west and the strata dip towards the south where the boundary fault is of greater magnitude.

The general characters of coal of the Barakar and Raniganj series of the Lower Gondwanas are given below :

Barakar	*Raniganj*
Low moisture (1 to 3%)	High Moisture (3 to 8%)
Low volatile (20 to 30%)	High volatile (30 to 36%)
High fixed carbon (56 to 65%)	Medium fixed carbon (50 to 60%)
Excellent steam coal and often excellent coking coal.	Generally poorly caking, though some are moderately so ; good gas coal and long flame steam coal.

The coal found in the Himalayan region is generally crushed and friable, but low in moisture and volatiles. In the peninsular area the lower seams are generally high in fixed carbon and low in moisture and volatiles than the seams above.

The classification adopted by the Indian Coal Grading Board (constituted in 1925) for trade purposes is given below :—

Grade	Low volatile	High volatile
Selected	Up to 13% ash over 7,000 cal.	Up to 11% ash. Over 6,800 cal.
Grade I	13 to 15% ash Over 6,500 cal.	11 to 13% ash Over 6,300 cal. Under 9% moisture.
Grade II	15 to 18% ash Over 6,000 cal.	13 to 16% ash Over 6,000 cal. Under 10% moisture.
Grade III	Inferior to the above	Inferior to the above

Subsequently, the Committee on Assessment of Resources formed under the Coal Council of India (constituted in August 1956) provided the following standard classification for Indian coals, besides adopting other uniform methods for calculating and categorising coal reserves (as proved, indicated, inferred and unclassified).

Rank Classification of coals. (after I.S.P.)

The figures for reserves shall be classified as follows according to the rank of the coal :—

I. Anthracite.

II. Bituminous.

(A) *Low to medium volatile coals or coking coals.* — Air dried moisture upto 2% and volatile matter usually not more than 35% on unit coal basis.

(B) *High volatile or high moisture coals.* — Air dried moisture more than 2% or volatile matter usually more than 35% on unit coal basis. Sulphur less than 1% in either case.

(a) Semi-coking coals.

(b) Weakly to non-coaking coals.

(C) *High sulphur coals.* — Sulphur more than 1%. These occur in Assam and although some of them are simi-caking they are not suitable for metallurgical purposes.

III. Lignite

The bituminous coal reserves shall be further classified according to quality on the basis of the analysis of seam samples, as follows :

(A) *Low to medium volatile coal or coking coal*

Class I	—	Ash not exceeding 17%.
Class II	—	Ash exceeding 17% but not exceeding 24%.
Class III	—	Ash exceeding 24% but not exceeding 35%.
Class IV	—	Ash exceeding 35% but not exceeding 50%.

(B) *High volatile or high moisture coal*

Class I	—	Ash moisture not exceeding 19%.
Class II	—	Ash moisture exceeding 19% but not exceeding 28%.
Class III	—	Ash moisture exceeding 28% but not exceeding 40%.
Class IV	—	Ash moisture exceeding 40% but not exceeding 50%

(C) *High sulphur coals*

No quality classification is needed.

Specific Gravity

Where reliable data are available, the following average specific gravity of each class within each category should be used :

(A) *Low to medium volatile coal or coking coal.*

(a) Class I	—	1.42
(b) Class II	—	1.47
(c) Class III	—	1.57
(d) Class IV	—	1.70

(B) *High volatile or high moisture coal.*

(a) Class I	—	1.40
(b) Class II	—	1.44
(c) Class III	—	1.55
(d) Class IV	—	1.70

(C) *High sulphur coal.*

(a) 0 to 5%	—	1.30
(b) 5 to 10%	—	1.34
(c) 10 to 15%	—	1.38

Abnormal Coals

Iron-ore	3.4	tons (3.45 tonnes)
Coal	3.0	tons (3.05 tonnes)
Limestone & Dolomite . . : .	1.00	ton (1.01 tonnes)
Magnesium-ore . . .	0.356	tons (0.36 tonnes)
	7.43	tons (7.87 tonnes)

Specifications of coal and coke for use in Steel Plants

Coke is to be carefully prepared and should conform to the following specifications :—

(1) It should be sufficiently hard to withstand crushing under the load of iron in blast furnace shattering test on 2 in./1½ in. = 82 to 92 per cent. or over.

(2) It should have good combustibility.

(3) It should have definite degree of porosity, preferably 42 per cent. or over.

(4) Ratio of cellular space to body of coke in per cent. of cell space is usually in the proportion of 44 and 56.

(5) It should be resistant to the solvent action of Co_2 in the upper section of the furnace.

(6) It should conform to 'Breslan test' for hardness (total on 40 mm.) 80 per cent. or over.

(7) It should conform to Haver's stability test—total on one inch screen should be 50 per cent. or over.

(8) Volatile matter should be less than one per cent.

(9) Fixed Carbon—75 per cent.

(10) Phosphorus—0.2-0.5 per cent. (maximum).

(11) Sulphur—1.5 per cent. (maximum).

(12) Alkali—should be absent in the raw material coal from which coke is manufactured.

(13) Ash percentage should be as low as possible (22.5 per cent. maximum on dry basis) and uniformly maintained.

Specifications of good Indian Metallurgical Coal (From F. R. I.-Report No. 2 The Blending of Coals)

(1) Swelling Properties—Must be free from harmful swelling.

(2) Sulphur content—Less than 0.60 per cent.
(3) Phosphorus content—Less than 0.15 per cent.
(4) Caking Index—15 or above.
(5) Ash—Less than 17 per cent. (Dry basis).
(6) Volatile matter—Around 26 per cent.
(7) Fixed carbon—57 to 58 per cent.

TISCO's specification of metallurgical Coal for use in the blast furnaces

(1) Swelling properties—must be non-swelling.
(2) Phosphorous—below 0.15 per cent.
(3) Sulphur—0.6 per cent.
(4) Caking index—15 and above (Tata index) B. S. Index—$1\frac{1}{2}$ than Tata Index.
(5) Ash—below 17 per cent.
(6) Volatile matter—26 per cent.
(7) Fixed carbon—57 to 58 per cent.

Requirements of coke to Pig iron are estimated to be of the order of 1:0.9. Further, it has been noted that for each increment of one per cent. ash in coke, full rate would be increased by four to five per cent. in the furnace and consequent fall by five to six per cent. in productivity.

Metallurgical coke is an essential ingredient in iron and steel industries. The Durgapur Steel Works have three batteries of coke ovens, each consisting of 78 ovens, which can carbonise 5,283 tonnes of dry coal into 3,962 tonnes of coke per day. The IISCO has a target of 4,200 tonnes of washed coal per day, and the Company's estimated annual requirement of coal is about 2.508 million tonnes.

The Durgapur Coke Oven Plant, a State Government undertaking, has a capacity of handling 1,321 tonnes of coal and coke breeze per day (1,255 tonnes of coal and 66 tonnes of coke breeze) with auxiliary plants for the recovery of by-products. The capacity may be doubled in the Third Five Year Plan period. A low temperature carbonisation plant of 711 to 1,016 tonnes per day capacity has been installed at Durgapur Cake Oven Plant to supply gas to the Durgapur Group of Industries. The daily surplus of about two million cubic metres of gas of 450 B. T. U. calorific valuewill be transmitted to Calcutta. Calcutta is now fed by Durgapur gas.

Coals are produced mainly from the Lower Gondwana region (Raniganj coalfield) and also to some extent from the extra-peninsular area (in the Darjeeling district) of the State.

Raniganj Coalfield

It is the principal coalfield in the State. The geology of the field is described in the Chapter on 'Geology'. This coalfield around Raniganj (23°36′ : 87°08′) and Asansol, about 200 km. west of Calcutta, is the easternmost of the Damodar Valley coalfields. It covers an area of about 1,550 sq. km. of proved coal bearing area.

Since the working of the first coal mine in 1774 by Sumner and Heatley, a quantity of about 362 million tonnes (Krishnan 1960, p. 341) of coalhas been produced from this field until 1950 which figure, however, appears to exclude the amount of coal lost at the site and/or by fire, flooding etc.

Some of the Raniganj coals, besides being excellent steam coals, are also found to be good blendable coals along with the Jharia coals for the manufacture of coke. The Sanctoria and Dishergarh seams are mostly semi-caking coals.

The Barakar coal seams are reported to be of generally inferior grade in the Gaurangdih—Churulia and Trans-Ajoy-Kasta areas and coal seams of the Raniganj measures are generally non-coking, as reported by D. R. S. Mehta (1956).

The coal reserves in the Raniganj coalfield as estimated by Mehta (1956) are given below :—

Kinds of coal (as per Indian Coal Grading Board's classification)		Million tonnes Upto 305 m. depth	Upto 610 m. depth
Caking (Selected & Grade I)		293	557
Non-caking (Selected & Grade I)		2,803	4,916
Non-caking (Below Grade I)		5,028	8,364
	Total	8,124	13,837
Coal already exploited		549	549
Available *in situ* reserves		7,575	13,288

The chief colliery areas in the Burdwan district are at Ramnagar,

Dishergarh, Salanpur, Asansol, Gaurangdih, Churulia, Charanpur, Kalipahari, Shibpur, Raniganj, Toposi, Kenda, Purushottampur, Ukhra and Kajora. Within the Trans-Ajoy portion of the field lie the colliery groups of Poripur (Poriarpur), Kasta, Arang, Raswan and the Hingla. Extension of the coalfield to the south of Damodar river is included in the Bankura district of West Bengal and in the Manbhum district of Bihar. Here, the colliery areas are located near Nadiha, Deilya (Deoli), Saltor, Parbelia and Kalikapur.

Recently, in the report of the Committee of the Assessment of Reserves, the Coal Council of India (Vol. II, 1963) has incorporated the latest data on the quality and reserves of Raniganj coalfield. In the following paragraphs, some of the more important data have been incorporated.

Coal Seams

The Raniganj coalfield contains economic coal seams both in the Barakar and Raniganj measures, the seams in the latter are of greater significance in this field.

Coal Seams of Barakar Stage.—At least 14 important coal seams (1.22 m. and above in thickness) of the Barakar series are reported. These include the following and are arranged in a descending order :—

Of these, the following are classified into medium, semi-coking, weakly coking and non-coking categories.

(a) *Medium Coking*

(i) Chanch—Begunia—Shampur No. I seam.
(ii) Ramnagar—Shampur No. IV seam.
(iii) Laikdih—Shampur No. V seam.
(iv) Shampur No. VI, Shampur No. III—Kharbaree, Shampur Top.

(b) *Semi-Coking*

(i) Gourangdih—Churulia and Kasta seams occurring east of Churulia upto Arang.
(ii) Pusai-Badjna seam.
(iii) Gopinathpur-Salanpur 'C' seam.
(iv) Metadih seam.
(v) Brindabanpur seam (and equivalent seam).
(vi) Salanpur D, Khudia No. I, seam just above the Brindabanpur seam.
(vii) Kalimati—Damagoria and equivalent seams.

(c) *Weakly Coking*

(i) Kasta bottom seam.

(ii) Churulia bottom seam.

(iii) Seam below Gourangdih-Jamgram seam.

(d) *Non-coking* (weakly caking to non-caking).

(i) Kasta seam (east of Afzalpur).

(1) Coal seam 0.91 to 1.09 m. (3 to 4 ft.)
(2) Chanch—Begunia—Rampur (?) seam 1 to 3 m. (3 to 10 ft.)
(3) Shampur No. 1 seam.
(4) Shampur No. 2—3.5 m. (12 ft.)
(5) Shampur No. 3—Kharbahi seam—4.27 to 4.57 m. (14 to 15 ft.)
(6) Shampur No. 4—Ramnagar seam—4.26 to 4.57 m. (8 to 10 ft.)
(7) Shampur No. 5—Laikdhi-Bahira—5.48 to 21.34 m. (18 to 70 ft.)
(8) Shampur No. 6—3 m. (10 ft.)
(9) Bahira 4—Salanpur 'D' seam—1.52 m. (5 ft.)
(10) Gopinathput-Bahira 5—Salanpur 'C'—Gourangdih—Churulia—Jamgram-Kasta seam 2.13 to 9.14 m. (7 to 30 ft.)
(11) Brindabanpur-Birsinghpur-Salanpur 'B' seam—2.74 to 8.23 m. (9 to 30 ft.)
(12) Kalimati-Damagoria-Salanpur 'A' seam—9.14 to 38.1 m. (30 to 125 ft.)
(13) Metadih seam—2.43 m. (8 ft.)
(14) Pusai-Merthadih-Farewell seam—1.52 to 8.23 m. (5 to 30 ft.)

Coal Seams of Raniganj stage.—The 12 coal seams (1.22 m. and above) of the Raniganj measures are as follows and arranged in descending order :—

(1) Hirakhun-Bharatchak-Narsamuda seam—1.06 to 2.44 m. (3 ft. 6 inch. to 8 ft.)
(2) Gopalpur-Upper Dhadka-Satpukhuria—Ghusick—Siarsol—Upper Kajora seam—1.21 to 6.21 m. (4 to 21 ft.)
(3) Ghusick 'A' seam—2.74 to 3.04 m. (9 to 10 ft.)
(4) Kushadanga seam—1.82 to 2.13 m. (6 to 7 ft.)
(5) Borachak—Nega—Jemeri—Raniganj—Lower Kajora — Jambad—Bowla—Bankola seam—2.18 m. to 13.7 m. (7 to 45 ft.)
(6) Lower Dhadka—Narainkuri—Banshra—Sonachora—Bonbahal seam—0.91 to 4.26 m. (3 to 14 ft.).
(7) Shripur—Toposi—Kenda—Chora—Purushottampur seam—0.91 to 9.14 m. (3 to 30 ft.)
(8) Bara Dhemo and Raghunathbati—Manoharbahal-Rana—Poriarpur—Satgram—Jotejanaki—Dobrana—Darula—Mandarboni—Sonpur seam—1.52 to 5.48 m. (5 to 18 ft.)
(9) Dishergarh-Dhasul (?) Chinchuria (?)—Samla—Gobindapur (?)—seam—0.6 to 5.48 m. (2 to 18 ft.)
(10) Hatinal—Koithi seam—0.91 to 3.65 m. (3 to 12 ft.)
(11) Sanctoria-Poniati seam—1.21 to 5.48 m. (4 to 18 ft.)
(12) Taltor-Gangutiya seam—1.21 to 1.82 m. (4 to 6 ft.)

Of the above, the grouping of the following seams of Raniganj

stage under semi-coking, weakly coking, and non-coking categories have been made on the basis of the tests by the Central Fuel Research Institute and incorporated in the report on Raniganj Coalfield, (Vol. II of the report of Committee of Assessment of Resources.) These are as follows :

(a) *Semi-coking*

(i) Dishergarh seam (west of Salma dyke).
(ii) Sanctoria seam.
(iii) Burradhemo-Raghunathbati seam (upto Panchgachia).
(iv) Hatinal.

(b) *Weakly coking*

(i) Poniati seam (upto Shibpur).
(ii) Dishergarh seam (Ninga-Bagra sector).
(iii) Dhasul—Chichuria seam.
(iv) Koithi seam (upto shibpur).

(c) *Non-coking (weakly caking to non-caking)*

(i) Poniati seam (East of Shibpur).
(ii) Koithi seam (East of Shibpur).
(iii) Samla—Govindapur seam.
(iv) Taltor seam.
(v) Monoharbahal—Rana—Poriarpur—Satgram—Jotejanaki—Dobrana—Darula—Sonpur—Mandarboni seam.
(vi) Shripur—Toposi—Kenda—Chora—Purushottampur seam.
(vii) Lower Dhadka—Narainkuri—Banshra—Sonachera—Bonbahal seam.
(viii) Barrachak—Nega—Jameri—Raniganj—Mangalpur—Lower Kajora-Jambad—Bowla—Bankola seam.
(ix) Kushdanga seam.
(x) Ghusick 'A' seam.
(xi) Gopalpur-Upper Dhadka—Satpukhuriya—Ghusick-Siarsol—Upper Kajora seam.
(xii) Hirakhun—Bharatchak—Narsamuda seam.
(xiii) Other local seams.

In this connection, it will be necessary to note that a prior treatment in the form of washing is required for further utilisation of these medium, semi-coking or weakly coking coals (where containing high ash) for blending with the metallurgical coal.

Quality

The Gondwana coals as a whole, are sub-bituminous to bituminous having ash content of 11 to 13 per cent. in the best quality. The ash content even goes upto 12 to 15 per cent. in many of the important

(c) *Weakly Coking*

(i) Kasta bottom seam.
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(i) Poniati seam (upto Shibpur).
(ii) Dishergarh seam (Ninga-Bagra sector).
(iii) Dhasul—Chichuria seam.
(iv) Koithi seam (upto shibpur).

(c) *Non-coking (weakly caking to non-caking)*

(i) Poniati seam (East of Shibpur).
(ii) Koithi seam (East of Shibpur).
(iii) Samla—Govindapur seam.
(iv) Taltor seam.
(v) Monoharbahal—Rana—Poriarpur—Satgram—Jotejanaki—Dobrana—Darula —Sonpur—Mandarboni seam.
(vi) Shripur—Toposi—Kenda—Chora—Purushottampur seam.
(vii) Lower Dhadka—Narainkuri—Banshra—Sonachera—Bonbahal seam.
(viii) Barrachak—Nega—Jameri—Raniganj—Mangalpur—Lower Kajora-Jambad —Bowla—Bankola seam.
(ix) Kushdanga seam.
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(xii) Hirakhun—Bharatchak—Narsamuda seam.
(xiii) Other local seams.

In this connection, it will be necessary to note that a prior treatment in the form of washing is required for further utilisation of these medium, semi-coking or weakly coking coals (where containing high ash) for blending with the metallurgical coal.

Quality

The Gondwana coals as a whole, are sub-bituminous to bituminous having ash content of 11 to 13 per cent. in the best quality. The ash content even goes upto 12 to 15 per cent. in many of the important

seams. The Chanch seam (Chanch Colliery), Begunia-Ramgarh and Laikdih seams (Voctoria West Colliery) of Barakar measures are strongly caking (caking index 12 to 16) having moisture 1.40 to 1.63 per cent. volatile matter (less moisture) 26 to 28.96 per cent., ash 9.41 to 13.39 per cent., fixed carbon (by difference) 56.02 to 62.00 per cent., the fuel ratio 1.93 to 2.41, and the calorific value (in calories) 7,022 to 7,632. The ultimate analysis (dry, ashless basis) of these seams show that the percentage of carbon varies from 85.12 to 85.83, that of hydrogen from 5.20 to 5.30 and oxygen 6.47 to 7.08. The coal from the Damagaria seam (Damagaria colliery) of Barakar measures is caking with 1.24 per cent. moisture, 23.00 per cent. volatile matter, 15.00 per cent. ash, 62.00 per cent. fixed carbon, having fuel ratio 2.70 and calorific value 7,149 calories. The proximate and ultimate analysis of some important seams of the Raniganj measures are given in Table 5 below :—

TABLE 5

Proximate analysis						Ultimate analysis (Dry ashless basis)				
Seam and Colliery	Moisture	V. M. Less moisture	Ash	F. C.	Fuel Ratio	C	H_2	O_2	Calorific Value (in calories.)	Remarks
Dishergarh (Saltor colliery)	1.83	35.95	11.68	50.54	1.41	82.84	5.88	9.03	7,074	Yields fairly hard porous coke.
Dishergarh (Sodepur 9 and 10 pits)	2.16	34.35	13.61	49.88	1.45	81.72	5.72	10.31	6,854	
Sanctoria (Sitalpur colliery)	2.31	34.78	11.84	57.07	1.47	82.50	5.63	9.62	6,983	Yields hard porous coke.
Satpukhuriya (Satpukhuria colliery)	4.67	32.80	11.70	55.50	1.69	—	—	—	6,873	
Ghusick (Muslia colliery)	4.10	33.80	12.70	53.50	1.58	—	—	—	6,791	
Lower Kajora (Kajora colliery)	7.20	32.80	12.08	55.12	1.68	—	—	—	6,859	
Jambad (Khas Kajora colliery)	5.19	36.98	12.24	45.59	1.23	79.15	5.63	12.95	6,807	

Proximate analysis						Ultimate analysis				
Seam & Colliery	Moisture	V.M. less moisture	Ash	F.C.	Fuel Ratio	C	H_2	O_2	Calorific value (in calories)	Remarks
Rana (Kankhya colliery)	5.82	32.50	11.50	55.00	1.71	—	—	—	6,842	
Poniati	2.93	35.43	9.83	54.68	1.54	—	—	—	7,382	Caking properties moderate,

In the western part of the coalfield, the seams of coking coals (like Laikdih, Ramnagar etc.) are low in ash, sulphur and phosphorus contents The Laikdih coal is being used to some extent for coking in blends with low volatile Jharia coals, but the rest goes for steam raising or gas making, or is exported. The blending tests in the Fuel Research Institute show that excellent metallurgical coke can bo had exclusively from the Raniganj coals. Excellent gas coke and coke suitable for ferro-manganese could also be prepared from them. Laikdih seam can be specially treated to produce coke for the manufacture of calcium carbide.

The major portions of Samla, Jambad-Bowla, Purushottampur seams in the eastern part of the coalfield are of inferior quality. The middle portion of these seams is lower in grade than the upper and bottom portions. The black coal produced from these collieries is low in ash and is suitable for low temperature carbonisation giving high tar yields. Otherwise, the seams represent potential supplies of coal for gasification, synthetic oil manufacture and power generation. The coals from Raghunathbatty seams are found suitable for producer gas generation and low temperature carbonisation. They could substitute the high quality Dishergarh seams used for these purposes. The Geological Survey of India had recommended a synthetic petroleum plant at Ondal where about 356 million tonnes of coal suitable for the purpose exist.

The prospects of Upper Kajora and Jambad-Bowla coals may not be very bright for the production of domestic coke of suitable strength, but these are not unsuitable for production of low temperature tar (highest yield at 600°C.) (Shrikhande and others, 1960, p. 15) The caking index of these coals is 3, ash content 14 to 18 per cent., moisture 5.3 to 6.3 per cent., volatile matter 34.8 to 44.4 per cent., and fixed carbon 41.4 to 55.7 per cent.

The following data are incorporated from the Report of Coal Council of India, 1963, on assessment of reserves in Raniganj coal field, (Vol 2).

In quality, the coal seams of the Raniganj stage are generally of high moisture and high volatile group. The moisture content ranges from 2 to 11 per cent., while the volatile matter (on unit coal basis) ranges from 39 to 44 per cent. It is reported that variation from four to seven units in the moisture even in the same seam, has been noted in the different parts of the coalfield. However, it has been observed that the moisture content tends to increase from west to east, and consequently the overall quality of coal deteriorates in the same direction. Thus, appreciable difference has been observed in respect of the caking properties from the same seam or its homotaxial equivalent from the different parts of the field.

The Sanctoria-Poniati (upto Shibpur) and Dishergarh seams (west of Salma dykes) contain generally coals of Class I quality (upto 19 per cent. ash + moisture) and are of semi-caking type. Deterioration of these coals to Class II quality with increase in the proportion of dirt bands has also been observed, as in the case of Dishergarh seam to the east of Salma dyke and Panihati seams east of Shibpur. These are of weakly caking type. Most of the coals form the different seams of the Raniganj coalfield are of Class II category having ash and moisture ranging from 19 to 28 percent. An increase of up to three units in the overall grade has been observed with inclusion of the dirt bands. The Class III coal (28 to 40 per cent. ash and moisture) are reported to be limited to a few areas, *viz.*, Dasul-Chichuria, Sonpur, Top Shirpur and Bhabar seams, which are reported to have ash and moisture, ranging from 29 to 33 per cent.

It is reported that the non-caking (or weakly caking) coals of Raniganj series occur largely to the east of Asansol, while the semi-caking and weakly caking coals are found to the west and north-east of Asansol.

In quality, the coals of Barakar age are marked by their low moisture content, having generally less than two per cent., with exceptions in the areas east of Churulia, where a higher percentage of moisture has been recorded. The coals of Barakar stage are generally of medium volatile type (26 to 35 per cent.) and occur in the areas eastwards of Churulia and in certain seams of Chatabar basin, where the volatile matter is recorded to be over 35 per cent. The coals from

the Barakar measure of the Raniganj coalfield are distinct from those of the Jharia coalfield in that there is no low volatile coal in the former. The coals of Barakar measure range from Class I to IV. A fairly wide variation (about 5 to 7 units) in ash content in the same seam has been recorded from the different parts of the coalfield and particularly so where the seam has been noted to stretch over extensive areas. The ash content is recorded to range from 15 to 38 per cent. and may show further increase with inclusion of the dirt bands

Unlike the Jharia coalfield, there are only limited occurrences of Class I coal within the Barakar measures in this coalfield. These are limited to the Chanch Begunia seam. Most of the coals generally grade into Class II, as in limited sections of Chanch Begunia, Rampur and Laikdih and in certain portions of Kasta and Salanpur A seams. The coals of the upper seam of Laikdih and above, are reported to be better in quality (Class I to II ; ash 15 to 24 per cent. and volatile matter 32 to 36 per cent.) than the older Gopinathpur-Kasta seams. The lower seams belong largely to Class III and Class IV quality (ash content ranges from 24 to 38 per cent.) with the exception of Salanpur special, Pusia-Badjna seam, Salanpur A and Kasta seams (in certain sections). Salanpur C (Mohanpur area) and Birsinghpur seam (Nirsa-Mirgana area) are of Class IV quality. The volatile matter of the lower seams is reported to vary between 26 and 40 per cent.

With the exception of Metadih, Shampur No. 6 (in Shampur basin), Salanpur D (near Alkusa) and Kharbari top seams, which belong to Class II grade (ash 20 to 24 per cent.), the local seams are largely of Class III quality with ash varying from 24 to 35 per cent., and volatile matter from 32 to 37 per cent.

Reserves

The total reserves of coal estimated from the Raniganj coalfield are about 5,900 million tonnes, down to a depth of 304 m., 19,285 million tonnes down to a depth of 609 m. and about 69,271 million tonnes down to depths in between 609 m. and 1,219 m. The grand total of reserves, estimated upto a depth of 1,219 m., is 26,212 million tonnes. The break up of these reserves is given below.

Depth range	*Reserve of coal in tonnes*
0—152 m. (0—500 ft.)	7,230,283,661
152—304 m. (500—1,000 ft.)	5,925,400,602

Depth range	*Reserve of coal in tonnes*
304—609 m. (1,000—2,000 ft.)	6,130,033,979
Total: 0— 609 m. (0—2,000 ft.)	19,285,724,242
609—914 m. (2,000—3,000 ft.)	3,628,611,200
9,14—1219 m. (3,000—4,000 ft.)	3,298,574,200
Total: 609 –1,219 m. (2,000—4,000 ft.)	6,927,185,400
Grand Total 0—1,219 m. (0—4,000 ft.)	26,212,909,642

These include 376 million tonnes of proved quarriable reserves (in the proportion of coal : overburden upto 1:5), 44.4 million tonnes of indicated reserves and 48.3 million tonnes of inferred reserves.

The Geological Survey of India have drilled a number of boreholes in this field particularly to the south of the Damodar river, and recorded extensions of coal measures. They have proved additional reserves of coal.

The Indian Bureau of mines have taken up intensive prospecting in a block, 23 sq.km. in area, and hence located the extension of the Raniganj coalfield to the south of the Damodar river. Already a reserve of about 100 million tonnes of coal has been proved by the Indian Bureau of Mines from this block.

The working of coal below a depth of 610 m. has already been started in the Chuchuria colliery of M/s. Bengal Coal Co.Ltd. and the workings are likely to extend to greater depths.

The possibility of extension of the Raniganj coal seams under the alluvium and laterite, which was considered as a probability on a reasonable basis, has already been confirmed at certain localities.

Coal is also likely to occur at great depths below the Panchet and Supra-Panchet.

The Raniganj coalfield has been worked since 1774 and the total production until 1950 was about 356 million tonnes (Krishnan,

1960, p.341). The recoverable reserves may prove to be less than 10 per cent. or so of the total on account of the included shale and stone bands within the coal seams. The actual recoverable reserves will also depend on the efficiency of mining practice in future and on the measures that may be enforced to prevent loss of coal due to selective mining. If the coal seams in the Raniganj measures below Panchet in the southern part of the coalfield are taken into account, the reserves are certainly enormous.

Except for caking coal these reserves, which are practically the double of those estimated in 1928, would last a long time at the current rate of consumption.

Exploratory drilling for accurate assessment of coal reserves and for opening new coal mines is being carried out by the Geological Survey of India since 1956. The exploratory work is mainly confined to the unexplored and unleased areas in the east and south-west of the coalfield in the following areas:—

(1) Ondal area in the eastern part of the coalfield in the Burdwan district.

(2) Nawada area south of the Damodar river in the Purulia district.

(3) Kulti-Salanpur area.

(4) Shyamdih-Bolkunda area in the Burdwan district and

(5) Dhangajhor area in the Purulia district.

1) *Ondal area.*—Deep drilling at places north of Dubchururia (23°34′40″ :87°13′35″) proved within a depth of 801 m. coal seams, each over 90 cm. thick, and of which eight have been correlated with the five major seams of the Raniganj coalfield, *viz.* Narsamuda, Upper and Lower Kajora, Bonbahal (VII) and Toposi-Kenda (VI) seams. The topmost coal seam was met at a depth of 548.6 m. From the proximate analysis of these seams, it appears that the quality has deteriorated. There is a general increase in the ash content and the moisture content is comparatively low. The borehole has confirmed the existence of the upper coal seams of the Raniganj series whose thickness varies between 610 and 914 m. The actual reserves proved by this borehole are about 5.4 million tonnes (200 m. around the borehole) (Roy, 1962).

(2) *Nawada (23°39′ : 86°49′) area.*—Five boreholes (RN-I to 5)

having a total depth of 3,885 m. have been drilled in this area between September 1957 to June 1960. These proved the extension of such important seams as Gopalpur, Borachak, Bara Dhemo and Dishergarh. The Dishergarh seam, 2.4 to 3.0 m. thick, has been encountered at depths of 381 to 610 m. containing about 15.3 million tonnes of selected grade metallurgical coal over an area of 3.2 sq. km. The reserves in the adjoining unexplored areas are expected to be very large. The first borehole (RN-1) met with more than 30 coal seams, each 1 to 1.2 m. thick, within a depth of 916 m. and is presumed to have passed through a fault which has affected the normal sequence. In the third borehole, 15 coal seams varying in thickness from 38 cm. to 1,1 m. have been found within a depth of 245 m., and the Dishergarh seam is met with below 597.4 m. Thirteen coal seams (including the Dishergarh), 50 cm. to 2.44 m. in thickness, have been met with in the fourth borehole within a depth of 502.3 m. One coal seam, 2.6 m. thick, has been found at a depth of 382.2 m. in the fifth borehole.

(3) *Kulti-Salanpur area.*—Three boreholes,one at Kulti and two at Salanpur area, completed during the period February 1960 to December 1961, have proved the existence of coal seams like Begunia (99 cm. to 1.83 m.), Ramnagar (10 cm. to 1.37 m,), and Laikdih (in two sections, 2.44 to 5.18 m., thick with a parting of 6.1 m.) of the Barakar measures below the Barren measures. The coal from these seams is of Selected Grade I quality with a caking index between 21 and 26 (B.S.S.).

(4) *Shamdih-Bolkunda area.*—Drilling in this area started in June 1961. The first borehole proved the Salanpur B (5.46 m.), Salanpur A (39.35 m.), Salanpur C (6.52 m.) and Salanpur Special (3.20 m.) seams between depths of 193.84 m. and 289.82 m. The quaiity of the coal varies from caking to semi-caking.

(5) *Dhangajhor area in the Purulia district.*—During the later part of 1961, the Geological Survey of India carried out drilling in the Dhangajhor area. From a total of 75.24 m. drilled, the presence of coal seams (5 to 79 cm.) in different boreholes has been proved within a depth range of 12.96 to 27.48 m.

Production statistics

The annual output of coal from the Raniganj coalfield has increased from 6.6 million tonnes in 1931 to over 11.18 million tonnes

in 1951 and to about 18.74 million tonnes in 1962. The production statistics of the Raniganj coalfield from the year 1955 to 1962 are given below —

Year	*Output (in tonnes)*	*Percentage of total Indian output*
1955	13,183,111	33.94
1956	13,002,495	32.50
1957	13,855,598	31.30
1958	14,443,769	31.40
1959	15,192,065	31.70
1960	16,636,209	30.00
1961	17,200,889	30.00
1962	18,737,100	30.50

The district wise break up of the coal production figures in tonnes in the State is as given below :

	1958	*1959*	*1960*	*1961*	*1962*	*Percentage total Coal*
Darjeeling	29,781	6,007	27,472	55,097	43,973	0.1
Bankura	7,382	7,404	6,842	7,695	8,916	—
Birbhum	91,950	98,089	108,734	105,676	116,844	0.2
Burdwan	13,600,504	14,247,889	15,410,810	16,155,338	17,733,630	28.8
Purulia	683,933	838,683	913,889	932,180	877,710	1.7

BARJORA COALFIELD

A new patch of fossiliferous Lower Gondwana rocks (Barakars) lying between Lat. 23°15′ and 23°27′ and Long. 87°13′ and 87°17′ and extending over an area of about 15.5 sq. km. around Barjora (23°26′: 87°17′), Bankura district, on the southern side of the Damodar river opposite Durgapur, has been discovered by A. Hunday (Krishnan, 1954).

The general dip of these beds is gentle, varying from 5° to 10° to the south-east. They comprise both greyish and reddish micaceous shales, overlain by coarse felspathic sandstones wich are sometimes ferruginous. A layer of pebbly horizon, 60 to 90 cm. in thickness, and composed mostly of sub-rounded and rounded bluish and white quartzite pebbles (ranging upto 7.62 cm. in diameter) is present in the sandstone beds overlying the soft grey shales. These grey shales contain the plant fossils *Glossopteris indica, G. communis, G. retifera, Gangamopteris cyclopteroides (?), Samaropsis* and *Cordaicarpus* sp.

Recent drilling of 26 boreholes in an area of 60 sq. km. by the Geological Survey of India (1956-57), besides confirming the presence

of coal seams in an area of 15.5 sq. km., has further proved the extension of the coal bearing Lower Gondwana formations below the alluvium and laterite over an area of 33.67 sq. km.

Altogether nine carbonaceous horizons were located. Of these the four horizons (Horizon I, V, VI, VII) are over 90 cm. in thickness. The partings between Horizons I and V range from 38 to 57.9 m. (125 to 190 ft.) while the individual partings below other horizons (V, VI and VII) range from 3 to 13.4 m. in thickness. The thickness of the Horizon I ranges from 1.12 to 2.87 m., of Horizon V from 0.66 to 2.69 m., of Horizon VI from 1.19 to 1.90 m. and of Horizon VII from 1.02 to 1.60 m.

The structure as revealed through drilling by the Geological Survey of India indicated that the Lower Gondwanas were deposited in the form of an elliptical basin with centripetal dips (3° to 16°) ; and these are remarkably free from faults and show an absence of the Talchirs. It is considered actually to comprise two basins with a separating ridge. The Barjora basin is thought to have been separated from the Raniganj coalfield as a result of the great post-depositional southern boundary fault. The Barakars in the Barjora boundary are now found to occupy a much higher elevation than those seen in the Raniganj coalfield, although originally the Barakars of these two detached fields might have been deposited simultaneously.

The tolal reserves estimated from these four major coal horizons within a depth of 152.40 m. (500 ft.) from the surface on the basis of drilling are about 27 million tonnes including 12 million tonnes of proved reserves (6.5 million tonnes with 35 per cent. ash and moisture and 5.5 million tonnes with 35 to 40 per cent. ash and moisture). The remaining 15 million tonnes are indicated reserves.

The horizon-wise break up of these estimated reserves is as follows :—

Horizon VII	— 3.41 million tonnes with	1.38 million tonnes proved
Horizon VI	— 7.31 million tonnes with	4.95 million tonnes proved
Horizon V	— 8.99 million tonnes with	2.70 million tonnes proved
Horizon I	— 7.28 million tonnes with	2.96 million tonnes proved
	Total—26.99 million tonnes with	11.99 million tonnes proved

In quality, the coal from these horizons belongs to Class III (Indian Standard Procedure, ash and moisture between 28 and 40 per cent.).

The overall moisture content of these coals varies from 2.78 to 8.57 per cent., the volatile matter ranges from 25 to 32 per cent. while the ash is over 15 to 26 per cent.

It has been indicated that the Horizons VI and I containing workable reserves of coal with 35 per cent. of combined ash and moisture may be suitable for use in thermal power stations.

An outcrop of coal, about 60 cm. in thickness has been reported near the boundary of the Gondwana-Archaean rocks west of Biharinath hill and east of Chak Baga village (23°35′ : 85°56′), in the north-western part of the Bankura district. The coal seam, in association with carbonaceous shales and felspathic sandstones of the Raniganj series, occurs under an overburden of 4.5 to 6 m. thickness. This deposit was worked for few months in 1949 by Shingdeo and Agarwala Co. The seam is lenticular and the quality is suitable for domestic fuel.

Coalfields in the Extra-Peninsular Region

In the extra-peninsular region, only the Lower Gondwanas are represented in the sub-Himalayan foothills. The coal seams in the Lower Gondwanas of the darjeeling and Jalpaiguri districts are mostly crushed. The strata dip northwards at high angles into the hills.

DARJEELING DISTRICT

Patchy occurrences of coal are recorded from almost the entire length of the Lower Gondwana rocks in the Darjeeling and Jalpaiguri districts. Hooker, in 1849 (cited by Fox, 1934, p. 42), recorded the existence of carbonaceous shales containing Damuda fossils near Pankhabari (26°50′ : 88°16′). In 1854, Piddington gave an analysis of 'earthy soot coal', probably from this band, containing 40.30 per cent. ash. In 1874, Mallet traced the band of Damuda rocks from Pankhabari eastwards to the neighbourhood of Daling (27°01′ : 88°46′) for a distance of about 48 km. Many seams of chrushed coal, 61 cm. to 3.35 m. in thickness, were found. Bose (1890) explored one band, 1.5 to 7.3 m. thick and 4.42 km. long, lying between the Lish and Ramthi rivers. Some of these coals are found to be of coking type He estimated a total quantity of *20.32* million tonnes of coal upto a depth of 305 m. in this area. This coal

is of anthracitic character and contains only traces of sulphur. An average analysis of eight samples showed :—

Carbon	59.56%
Volatile matter	22.94%
Ash	17.42%

The coal seams dip steeply (40° to 90°), the directions of dip varying between north-west and north-north-east. The flaky and powdery coal seams vary in quality from semi-bituminous to anthracite. These are lenticular in nature and are not traceable over any great distance. They may also be repeated due to folding.

Distribution

(1) Two thin coal seams, 15.24 cm. wide, are seen in the right bank of Balasan river (26°49′ : 88°15′), south of the Gayabari Tea Estate in the foothills of the Darjeeling district. These are of no economic importance.

(2) *Pankhabari area :* Most of the coal seams here are less than 30 cm. in thickness. In the Dobi *khola,* however, there are at least two coal seams 61 cm. and 2.74 m. thick. The thicker seam contains shale and sandstone intercalations. Plant fossils (like *Glossopteris, Schizoneura* and *Vertebraria*) are found in this locality. At least four to five coal seams are found in the Rungsung *khola* section east of Pankhabari, but none of them exceeds 30 cm. in thickness. In the Rakti *nadi* further to the east, the width of the Damudas is about 800 m., and there are at least eight to nine coal seams having a maximum width of 152 m., dipping steeply in the northerly direction.

(3) *Tindharia (26°51′ : 88°20′)—Mahanadi section :* The best coal seam found by Mallet (1877) in this area is about 3.4 m. thick. In the Mahanadi section a few coal seams with a maximum thickness of 91 cm. are seen, but they are not of much economic importance. The sandstones and shales here contain *Vartebraria.* Stefanski (1948) has also noted the existence of at least four thick (9.14, 10.67, 4.57, 1.52—1.83, and 0.91 m.) coal seams in the Tindharia-Mahanadi coalfield. The quality of the coal is rather poor. A few coal seams are found in the Mana *khola.* Of those, one 91 cm. thick

coal seam, occurring 400 m. upstream of the confluence of the Mahanadi and Mana *khola*, is of fairly good quality.

Balasundaram (Roy, 1961) has found several coal seams around Tindharia, some of which are 1.22 to 1.52 m. thick and of fairly good quality.

(4) *Kalijhora (26°55' : 88°27')—Tista section :* Balasundaram (Roy, 1961) noted about 15 coal seams, none thicker than 61 cm., below the Kalijhora Inspection Bungalow. One six metre thick coal seam is exposed at the confluence of the Kalijhora stream with the Tista. Stefanski (1948) also reported numerous poor quality coal seams usually of 90 cm. thick over a 1.6 km. long belt in the Kalijhora-Tista area. A few coal seams are found to the north of 17½ mile-stone on the Siliguri-Kalimpong Highway (N.H.31/A) near the Damuda-Daling boundary. One of these coal seams is 1.83 to 2.13 m. thick, and is practically vertical. There are a few coal seams, varying in thickness from a few centimetres to 4.27 m. and extending over a distance of 31 m., exposed in the Kali *khola* section of the Ryiang block.

(5) *Tista to Lish nadi :* Thin coal seams, less than 60 cm. thick, are found to the east of the Tista upto Lish *nadi* in the Kalimpong sub-division, and are not economical to work.

(6) *The area between the Lish and Churanthi streams :* The most promising coal seams are noticed in the 3.2 km. long belt between the Lish and the Churanthi streams. The Bagrakote colliery is situated in this belt. The Bagrakote seam attains a maximum thickness of 13.72 m. In the Churanthi section, the Damudas attain a maximum thickness of 800 m., in which two coal seams, 1.52 m. and 3.35 m. thick respectively are found. At places these seams are 3.1 m. and 7.6 m. thick, and continue for about 610 m. along the strike. The analyses of these coals show—

Moisture	1 to 4.83%
Volatile matter	13.60 to 18.00%
Fixed Carbon	62.80 to 63.80%
Ash	18.93 to 22.90%

The nature of the coal is (i) non-caking, (ii) caking and (iii) slightly caking. The Darjeeling coal, being generally in powdered form, requires briquetting before use.

The production of coal from the Dalingkote colliery of the Himalayan Mineral Industries Ltd. commenced in 1944, when 532

tonnes of coal were produced. During 1952, the output increased to about 36,029 tonnes and almost the whole of it was consumed by the brick fields in North Bengal and North Bihar.

(7) *Churanthi-Ramthi block :* Three major coal seams with lamprophyre intrusives are found along a 1.6 km. long belt in this block.

(8) *Ramthi-Gish nadi block :* A few coal seams having a maximum thickness of 13 m. are found in the Nimuni and Nali *kholas* towards the east.

(9) *Gish-Lethi nadi block :* Excepting the coal occurrences at Nimuni and Nali *khola*, the rest of the area has not been properly explored.

(10) *Mangzung block* (26°58′ : 88°40′) : One 9.14 m. thick coal seam dipping at 60° towards the north-east is exposed in the Mangzung *khola* within an isolated and faulted Damuda patch. The seam is traceable for a distance of 30 m., but the width is reduced along the strike. Balasundaram (Roy, 1961) suggested for a prospecting in this area taking into account the unstability of the left bank.

(11) *Sukha (Phagu) block :* This is another isolated and faulted block of Damudas dipping at 40° to 50° towards the north-east. Sporadic occurrences of several coal seams (non-caking with high ash content, and with carbonaceous shale partings), usually thin, from less than 15 cm. to a few metres in thickness have been reported from the Phagu and Chel blocks of the Kalimpong Forest Division. Two coal seams, 61 m. and 7.62 m. thick, occurring along the east bank of the Phagu *nala* and at the watershed of the Nali *khola* respectively, seem to be promising. The analyses of these coals by Chandra (West, 1950) are as follows :—

	(1) per cent.	(2) a per cent.	(2) b per cent.
Moisture	2.38	5.08	3.06
Volatile matter (less moisture)	6.10	10.82	8.82
Fixed Carbon	63.10	22.62	58.04
Ash	28.42	61.48	30.08

1 Phagu *khola*.
2 (a) From a tributary of Nali *khola*.
2 (b) From a tributary of Nali *khola*.

Mining of coal in these landslide areas is at times hazardous, but many officers of the Geological Survey of India, who visited these areas along with the members of the Flood Control Committee fo the Government of West Bengal, are of the opinion that the

area should be properly prospected for coal, and prospecting licences and mining leases should be granted to tap the coal resources, giving due precautions to landslips, de-forestation, soil erosion and floods.

(12) *Chel block*: Five thin coal seams occur in the Chel river section, south of the old bridge at Sombarihat (26°58′ : 88°42′). The analysis of one sample shows moisture 1.92%, volatile matter 9.84%, fixed carbon 46.78% and ash 41.46% (West, 1950, p. 114).

(13) *Kumai-Naksal Khola* (27°01′ : 88°51′) *block*: This isolated block of Damuda rocks extends over a distance of about 7 km., from Murti eastwards upto the Jaldakha river at the Bhutan border. The area is drained by the Kumai *nadi* and the Naksal *khola*. Two coal seams, 2.13 and 7.62 m. thick, with intercalations of sandstone and shale, are present in the Naksal *khola*. A few coal seams are also found in the Kumai *nadi* section.

(14) *Tar Chu nala* (27°07′ : 88°30′): The occurrence of coal has been noted in a small and isolated Lower Gondwana outcrop in the Tar Chu *nala*, a few kilometres north-east of the Kalimpong town.

The analyses of some of these coals are given below (Fox, 1934, p. 50):—

	1	2	3	4	5
Moisture (%)	1.60	16.10	4.21	14.54	4.72
Volatile matter (%)	10.40	15.47	14.09	8.86	22.16
Fixed carbon (%)	61.76	51.85	62.56	63.96	60.24
Ash (%)	26.24	16.58	19.14	12.64	12.88
Colour of ash	red	red-grey	brown	grey	
Caking property	nil	cakes strongly	cakes strongly	cakes strongly	

1. Ramthi valley (No. 30).
2. Churanthi (No. 25) from a depth of 2.13 m.
3. Churanthi (No. 7) from a depth of 2.74 m.
4. Lish (No. 3) (Lish valley).
5. Lish (No. 1).

Fox remarked that surface samples did not possess caking properties, but the samples from a depth of 1.52 to 1.82 m. were often of caking quality.

Reserves

In the Lish—Ramthi area, P. N. Bose (1890) discovered at least 10 seams each over 1.52 m. thick with less than 22 per cent. ash. This works out to 101.6 million tonnes of coal in an area of 5.18 sq. km. Also Bose estimated a reserve of about 20.32 million tonnes of good quality caking coal available from this area.

Stefanski (1948) estimated the following reserves of coal in the Dalingkote coalfield :—

	Maximum reserves of coal (in tonnes)	*Minimum reserves of coal (in tonnes)*
(a) Under normal condition	154,504,181	123,603,093
(b) After deducting 10% as possible loss due to mining	138,545,728	111,242,921

His calculations are based on the assumption that the three main coal seams (taking 18.9 m. as the total thickness) will continue for a distance of 6.44 km. and down to a workable depth of 548 m.

According to Stefanski, the quantity of good quality coal in the Dalingkote coalfield with a calculated minimum reserve of 12.2 million tonnes upto a depth of 548 m. should last for 10 to 12 years, if exploited at the rate of 1.21 million tonnes per year by modern mining methods. If mining could be extended down to a depth of 1,097 m., the coalfield should last for another 10 years. According to him, the rest of the coalfield upto the Phagu *nala* would yield another 264,172 tonnes of good coal. He suggested prospecting in the area between the Phagu *nala* and the Jaldakha river.

Production Statistics

The first attempt to mine coal on a commercial scale was undertaken in 1896 by a firm in Calcutta. A colliery was established at Dalingkote and a total quantity of 7,347 tonnes of coal were raised till the enterprise closed in 1900 (Fox, 1934, p. 49). The Dalingkote colliery near Bagrakote started production from 1944 and the output in 1952 was about 36,000 tonnes. The coal production from the Darjeeling coalfield was 27,570 tonnes in 1960, and 55,097 tonnes in 1961. The production figures of coal from the Darjeeling district from the year 1950 to 1961 are given below :—

Year	*Output (in tonnes)*	*Percentage of total Indian output*
1950	15,609	0.05
1951	17,885	0.05
1952	36,029	0.10
1953	39,913	0.11
1954	29,963	0.08
1955	23,657	0.06
1956	31,006	0.09
1957	37,929	0.10
1958	29,781	0.10
1959	6,007	
1960	27,472	0.05
1961	55,097	0.10

JALPAIGURI DISTRICT

A thin seam and a few lenticles of graphitic coal are reported by A. Lahiri (1937) in quartzitic sandstones of Gondwana age lying between the Tertiary rocks in tho south and the Buxa quartzites to the north at about three kilometres N.N.W. of Jainti (26°45′ : 89°38′). The seams are exposed in the Jainti river bed. The Gondwana strip has a N.N.E.-S.S.W. strike with 75° to 80° dip towards north-west. It is about 100 m. thick and is traced for a distance of about five kilometres to the east upto the Baje *khola*. The coal is lenticular and discontinuous, shining black, flaky and graphitic at places. Some small lenses of graphitic coal occur in the thin bands of Gondwana rocks. One analysis of Jainti coal given by Lahiri shows—moisture 1.58%, volatile matter 8.19%, fixed carbon 66.42%, and ash 23.81%.

The analyses resemble closely those by Mallet's for the Darjeeling coal.

Probable extention of the coalfields in West Bengal

The sub-surface geology of Gengetic West Bengal is known through the deep drilling made either for water or for petroleum. The extension of the Raniganj coalfield in the Ondal and Durgapur areas has been proved by deep drilling. It may also be assumed that the Rajmahal coalfield may extend towards south and south-east to link up with the Damodar Valley basin and the possibility of coal being present even in the Raniganj stage can not be ruled out (Ahmad, 1959, p. 11). Gondwana basins may be found within the Archaeans towards the east. The chance of exploiting this coal, if found, may be limited because of the thickness of the overlying alluvium. The thickness of the alluvium under which Gondwana coal has been discovered at Bogra, East Pakistan, is about 2,438 m. The gneissic rocks which form the basement lie within a depth of 300 m. in the gap between the Rajmahal and the Garo Hills. Mallet (1875) also envisaged that the Darjeeling coal basin may extend towards the Peninsular India. Stefanski (1948) also thinks that the Gondwana coal formations of Phagu Chu in the Kalimpong sub-division have been pushed forward, and are now covered by the alluvium over a wide area.

Production statistics of coal from West Bengal

There are about 228 coal mines in West Bengal with an employment capacity of about 99,000 workers per day during 1960-61. The

total production of coal in West Bengal from 1800 to 1950 was about 356 million tonnes. In 1962, the production was about 18.8 million tonnes.

The production statistics of coal from West Bengal, *vis-a-vis* the all-India production and values from the year 1951 to 1962 are given in Table 6 below.

Table 6

	West. Bergal		All India	
Year	Output (in tonnes)	Value in Rupees)	Output (in tonnes)	Value (in Rupees)
1951	9,800,345	142,609,445	34,984,934	504,811,359
1952	13,504,276	154,747,474	31,886,150	536,235,440
1953	10,390,305	152,263,305	36,557,789	527,677,372
1954	10,773,175	157,390,358	37,475,410	539,196,417
1955	11,520,000	167,600,000	38,839,000	560,300,000
1956	11,460,000	182,800,000	39,910,000	635,400,000
1957	13,892,527	257,527,000	44,204,000	814,022,000
1958	14,473,550	284,897,000	46,056,000	898,742,000
1959	15,198,072	303,350,000	47,800,000	984,194,000
1960	16,467,747	339,654,000	52,593,000	1,088,447,000
1961	17,256,000	357,421,000	56,065,000	1,171,939,000
1962	18,781,000	401,415,000	61,340,000	1,338,537,000

Coal Consumption

The railways are the biggest consumers of coal in the country, with the Iron and Steel Industries coming next. Of the total Indian production, the respective percentages of coal consumption by various industries and agencies during 1959 and 1960 are given below.

	1959 (Per cent.)	1960 (Per cent.)
Railways	36.1	35.8
Iron and steel factories	14.4	17.2
Electrical industries	10.0	11.3
Cement factories	5.5	5.4
Brick works	5.46	2.3
Cotton mills	4.1	4.0
Chemical industries	2.5	2.1
Paper mills	1.6	1.7
Jute mills	0.7	0.7
Bunkers	0.4	0.3
Others (small industries, like lime, sugar etc.)	20.1	19.4

Utilization and Prospects

The utilization of coal for the generation of power in the country is likely to increase considerably in the near future in the context of an

ambitious programme of generation of thermal power. The present share of electrical industry in the consumption of coal is likely to be of the order of 10 to 11 per cent. (using five million tonnes of coal) in the country, while the proportionate share of power generated from coal, petroleum and hydel source is 74 per cent., 14 per cent. and 12 per cent. respectively. The cost of generation of each unit of electrical energy from hydel source, coal, petroleum and nuclear source is worked out to be approximately 1.2 P., 4 P., 3.5—4 P., and 4 P. respectively. The problem of harnessing nuclear energy for power is, however, still in an infant stage.

It is estimated that in India, for the generation of one kilowatt of electrical energy about 790 to 930 gm. of coal is necessary.

The recent methods of utilisation of low grade coal (with 40 per cent. or more ash) directly in new thermal power plants of the country from the open cast mines of the thick seams is indeed a revolutionary beginning in this respect and will definitely go a long way in ensuring further reduction in price and in an economic generation of thermal energy on a more competative basis than had hither to been possible.

Simultaneously, an economy in fuel consumption should receive the attention *vis-a-vis* the ultimate conservation of coal. The anticipated demand for coal by 1975 for the generation of thermal energy in this country is estimated to be of the order of 50 million tonnes.

The other secondary sources of fuel and energy are from wood and cattle dung used in the villages and these need early replacement by coal in the form of soft coke. This would consequently release a very great amount of the much needed cattle dung manure to step up agricultural production. In terms of energy value, roughly 100 million tonnes of coal will be necessary for substituting cattle dung and wood as fuel. It may also be noted that one tonne of charcoal is the product of five tonnes of wood made available through the destruction of 0.001 hectares of forest whereas a quantity of 1.35 tonnes of coal produces one tonne of coke and this contains the same heat energy as that of 0.86 tonnes of charcoal.

Such requirements in the rural and urban areas of West Bengal can be estimated as 7.4 million tonnes of coal for producing 6.1 million tonnes of soft coke for a population of 35 millions. This is expected to release 71 per cent, of the cattle dung (equivalent

to about 67 million tonnes) now estimated to be used as fuel, towards their use as manure.

Thus planned growth of coke industry should be fostered immediately. This will automatically be the fore-runner of many by-product industries, such as ammonia, sulphate, crude and road tar, benzene solvent, toluene, napthalene, xylene, motor benzol, naptha, xylol, pyridine, middle oil, creosote oil, anthracene oil, anthracene, pitch, carbolic acid, lysol, cresylic acid, disinfectant powder, etc.

Some of the other coal-based chemical industries, which ean be developed by the processing of benzene, toluene, xylene and napthalene are polyester resins polystyrene, phenol-formaldehyde, resins, alkyd resins, penta-chlorophenol (wood preservative), salycylic acid, nylon fibre, propylene and poly-propylene from coke oven gas, and carbon black from anthracene oil. These deserve attention for an early establishment of relevant units for the large scale utilisation of the high volatile coals in the State.

Similarlv an early establishment of synthetic oil plants, utilising medium to low grade coal (in the proportion of .7 : 1) near Ondal area, as suggested by the Geological Survey of India, should receive an early attention.

It is, therefore, necessary that an integrated policy of expansion of coal production in this State through mechanised mining in a scientific way on the basis of detailed exploratory data, should be greatly encouraged. Washing and briquetting of coal, and amalgamation of small uneconomic collieries with economic ones, are some of the measures suggested in this respect. Novertheless, an early solution of the transport bottleneck, by introducing large size wagons, developing roads and transport with large capacity trucks and by developing the water-ways, where possible, is needed in the State, and as such it requires an early action. For rational utilisation, studies in the suitability of maketing of different grades of washed and unwashed coal, middlings, as well as the by-products need also be taken up on a planned basis.

In course of assessment of the coal resources, particularly in the hitherto unexplored alluvial areas, the Geological Survey of India undertook regional exp'oration in recent years. Some of these areas are in Ondal, Kulti-Salanpur, Shamdih-Bolkunda areas in the Burdwan district, and Nawada in the Purulia district.

Similarly in the newly discovered Barjora coalfield in the Bankura district, the regional boreholes confirmed the presence of workable coal seams.

Assessment of the lay and disposition of the Dishergarh seam and its proved reserves of coal, required for deep mining in the seam (in Public Sector), is the main objective of this intensive exploration. Some other areas of the Raniganj coalfield, which have prospects of developing other seams at comparatively shallow depths, are also to be explored in detail in the near future.

Investment

Coal, being the vital mineral of this State, can easily claim a maximum share compared to other minerals in the investment for the expansion of mining and related industries. An investment of Rs. 1256.6 millions is proposed (Techno-economic survey of West Bengal) during 1961 to 1971 for an expansion of the industry, including Rs. 45 millions for the establishment of a coal washing plant with a capacity of 2.24 million tonnes per annum. This is anticipated to increase the production of coal in the State from the present 19.08 million tonnes (1962) to 53 milllon tonnes by 1971, absorbing thereby an additional number of 33,000 persons.

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Peat

Peat is an accummulation of partly decomposed vegetable matter which represents the first stage in the formation of coals.

H. F. Blanford (1864) described a peat bed 30 cm. thick at a depth of six metres from the surface in a tank at Scaldah in Calcutta It is overlain by a band of clay with sand and tree stumps about three metres thick. His conjecture that the bed extends over a wide area on both sides of river Hooghly proved correct by later findings. He thought it too impure to be used directly as fuel. A sample, 9.1 m. below the surface at Chitpur, Calcutta, yielded on analysis, carbon 16.7 per cent., volatile matter and moisture combined at 62.0 per cent. and ash 21.3 per cent.

Recently, occurrences of such peat at depths ranging from 1.83 to 10.67 m. have been noted in and around Calcutta. These were found at King George V Dock, between Howrah and Sealdah, at the time of drilling for the alignment of the proposed underground railway, at Dhakuria and Beliaghata, during excavations of lakes and during the sinking of a cable shaft in the Botanical Gardens at Shibpur, Howrah (Coulson, 1940). Peat beds are also found on both sides of the river Hooghly at depths ranging from 5.5 to 10.67 m. (Fox, 1931). One peat sample collected from a well at the village Bora in the Hooghly district analysed—fixed carbon 17.08 per cent., volatile matter 35.90 per cent., moisture 10.62 per cent. and ash 36.08 per cent.

The peat occuring at Calcutta appears to be detrital in character. It contains some drift material showing that it accummulated in a large marshy lake which has since been silted up and is now traversed by the Hooghly. As no marine or brackish water fauna has, so far, been detected in these peat beds, it may be considered as a fresh water

deposit. Piddington (1854) has described a formation resembling peat in the *jhils* (low marshy land) of southern Bengal. The principal plant which is concerned in its production is a wild variety of rice *Oryza sylvestris*. These are used to some extent as manure, but are not suitable for use as fuel.

Lignite

Lignite or brown coal represents the second stage of coal formation. It is brownish black in colour and is made up of woody matter embedded in macerated and decomposed vegetable matter. It is banded and jointed, and disintegrates after drying in air. It is subject to spontaneous combustion, and has low heating value (Bateman, 1942, p. 628).

Patchy occurrences of lignite are reported from the Siwalik sand stones fringing the Himalayan foothills in the Darjeeling and Jalpaiguri districts.

Darjeeling district : Herbert, in 1830, noticed bright lenticles and nests or lignite within the Siwalik sandstones in the Tista valley, and Oldham in 1854 reported these from the Sivok or Chawa stream (26°53′ : 88°32′) and also along the Nimi *khola* about one kilometre upstream from its confluence with the Dethi *nadi* in the Kalimpong Forest Division. These are also found in the Mahanadi Valley. Four specimens (sp. gr. 1.01) analysed b Piddington (cited by Fox, 1933, p. 48) gave, fixed carbon 57.56 per cent., volatile matter 30.08 per cent., moisture 8.20 per cent. and ash 3.97 per cent. The low ash content suggests that this material probably represents lignitic tree stems, while the high volatile matter distinguished this coal from the Damuda coal found in the same area.

Jalpaiguri district : Isolated outcrops of lignite exposed over large areas were reported by Godwin Austen in 1865 near Buxa Fort (26°45′ : 89°38′), and near a place 3.2 km. E.N.E. of Jainti (26°42′ : 89°41′). This lignite contains only a small percentage of ash. Good deposits of fair quality lignite are also reported from the western side of the Jainti river about 2.4 km. from Jainti and also in the Buxa hill 3.2 km. N.N.W. of Jainti.

The deposits in the Buxa hill are stated to be (61 m. x 152.4 m. x 30.5 m.) on the plane of bedding where several isolated patches have been located. These are Scarcely more than three millimetres each in

thickness. A sample of lignite (colour *Japan rose*) from a *nala* section, east of Santhrabari-Buxa Duar bridlepath, on anlysis by Chandra West 1960), gave the following result :—

Fixed Carbon	43.01
Volatile matter (less moisture)	14.07
Moisture	8.46
Ash	34.46
Colour of the ash	*Japan rose.*

The deposit, from the present state of knowledge, appears only to be of academic interest.

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CHAPTER X

CLAYS

General

Clays are the weathered products of silicate rocks containing sufficient hydrous aluminium silicate in softened condition to produce a plastic or semi-plastic mass when tempered with water (Wilson, 1927, p. 7). Depending on the geological mode of formation, clays may be residual, colluvial or transported (Ries, 1927, pp. 36-37). Residual clays are formed either by the decomposition of silicate minerals of rocks (kaolinisation), by leaching of carbonate rocks, or by the disintegration of shales, and by the lateritisation of rocks in tropical countries (lithomargic clays etc.) Residual clays may also be formed by hydrothermal solutions and by meteoric waters. Clays are also classified on the basis of their physical properties and general use in the industries. They are termed as plastic clays, refractory clays, vitrifying clays etc., and as kaolin (china-clay), ball clays, etc. Clays are also termed as ferruginous, argillaceous, siliceous, carbonaceous, aluminous, calcareous etc., depending on their chemical and mineralogical composition.

In recent times, detailed work has been done on the mineralogy of clays, their physico-chemical properties, and their ultimate suitability and use in varied industries. Illite, montmorillonite, halloysite, kaolinite, dickite, nacrite are some of the important clay minerals.

In West Bengal, good deposits of clays have beed found in the districts of Purulia, Bankura, Birbhum, Midnapur and Darjeeling. Recently, the Geological Survey of India have carried out detailed investigation on these clays. The pottery, ceramic and allied industries are well developed in this State and occupy a premier position in India. The quality of the products is also comparable to foreign standards. The country now earns valuable foreign exchange by exporting these products.

Common Clay

Common clays are of universal occurrence, and enormous quantities of them are available from the alluvial tracts which

constitute about 60 per cent. of the area of the State of West Bengal. They are made up of a mixture of clay minerals like kaolinite together with impurities like quartz, mica and organic matter. The village potter uses suitable earth from nearby places for manufacturing roofing tiles, domestic pottery and bricks. These clays vary enormously in quality from place to place giving rise to fired products of different colour, varying porosity and strength. The clay figures of Krishnanagar in the Nadia district have been famous for centuries. The images of Hindu gods and goddesses made out of Ganga silts and clays at Kumartuli in Calcutta are famous for their fine craftsmanship. The *terra-cotta* of Bankura and Birbhum have also been famous for centuries. Recently, it has been found that Ganga clays are suitable for making artistic clay objects. These could also be used for modelling after proper mixing with other plastic clays.

Kaolin or China-Clay

Kaolin or china-clay is distinguished by its low plasticity, white colour, softness, ease of dispersion in water and in other liquids, and by its extreme fineness of the ultimate particles. It consists essentially of micro-crystalline kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) and other clay minerals like illite, dickite etc. Typical kaolin is a refractory, white burning clay having a sp. gr. 2.6-2.68, and fusion point at 1,785°C. On burning, it shrinks by about 20 per cent. When raw, it sticks to the tongue softly and gives out an earthy smell. It is low in iron, calcium, magnesium and alkalis. Pure kaolin contains about 50 per cent. silica, 39 per cent. alumina, and 14 per cent. water, but kaolin of commercial grade often contains small amounts of impurities like quartz, oxides of iron and titanium, and minerals containing calcium and magnesium together with alkalis, soda and potash.

Raw clay, as obtained from the mines is crushed, screened to remove pebbles and grits, washed and carried off with water and allowed to settle in tanks, scrubbed and filter-pressed, dried and powdered, and then sieved into required mesh sizes for industrial uses. The amount of pure kaolin which can be won from a rock by crushing and washing rarely exceeds 25 per cent. of the whole.

Uses and Specifications

China-clay is one of the essential raw materials in ceramic industry which consumes nearly half the annual production of the state, and it is also used extensively in textile, paper, rubber and paint industries. Smaller quantities are used in cosmetics, chemical and pharmaceutical industries, as insecticides and in the manufacture of ultramarine blue etc.

Commercial china-clay should be white and free from gritty and tinting material as far as possible.

Pottery industry.—Such properties of china-clay, as plasticity and strength before firing and colour after firing, are very important for industry. China-clay used in this industry is also tested for vitrification, porosity and contraction after firing.

British manufactureres prefer clay, as free as possible from mica, quartz and ironbearing minerals. The material should contain about 39 per cent. alumina, 46 to 47 per cent. silica and have about 12.5 per cent. loss on ignition. The content of iron (Fe_2O_3) should not exceed 0.75 per cent. and that of titanium oxide (TiO_2) 0.1 per cent. About 30 per cent. should be under one micron in diameter.

The yellow colour imparted to china-clay may not be objectionable in pottery, if it is due to organic matter, but colour due to oxide of iron is often objectionable.

Almost all the pottery manufactureres in India use indigenous china-clay. A very few firms, such as the Bengal Potteries Limited, Calcutta, use a small quantity of imported clay along with the indigenous clay to improve the quality for use in the manufacture of high class wares.

The Bengal Potteries Ltd., Calcutta; the Bombay Potteries Ltd., Bombay; the Parshuram Pottery Works Ltd., Morvi; the Digvijay Tiles and Potteries Ltd., Jamnagar; the Scindia Potteries Ltd., New Delhi; the Charminar Pottery Works, Secunderabad, etc. are some of the important consumers of china-clay for the manufacture of earthenware, crockery, stoneware, sanitaryware and refractory goods. The specifications of various firms differ with each other to some extent. However, the chemical composition of china-clay generally used by the Bengal Potteries Ltd. and the Parshuram Pottery Works Ltd., is as follows :

Constituent	Bengal Potteries Limited	Parshuram Pottery Works Limited
	(per cent.)	(per cent.)
Silica	49.18	46.25
Alumina	37.49	37.70
Iron oxide	0.52	0.53
Titanium oxide	0.35	—
Magnesia	0.75	0.25
Alkalies	0.04	0.43
Loss on ignition	11.62	13.80

Textile industry.—China-clay is mostly employed in the textile industry in conjunction with suitable binders to give weight and body to cotton fabric. China-clay, to be used in textile industry, should be pure white in colour and free from any yellowish tint or added colouring matter, such as ultramarine. Grit is most objectionable, as it may tear the strands of thread during manufacture. The texture or feel of the clay, when made into a thick paste with water, is also regarded, by some users as a useful criterion for its suitability. Calcium carbonate and iron oxide are also objectionable and not more than a trace of these compounds should be present.

The Indian Standards Institution has laid down specifications for china-clays, for textile and paper industries (IS:1092—1957). There are two grades. Grade I is intended for use as filler and sizing material in textile industry and for coating in paper industry. Grade II is intended for use as a filler in paper industry. The specifications are given in Table 7 below :

TABLE 7

Sl.No.	Characteristics	Requirements for Grade I	Grade II
(i)	Particle size, per cent. by weight of the material passing through IS sieve 8 (75 microns aperture), min.	99.75	99.5
(ii)	Loss on ignition, per cent. by weight, max.	15	15
(iii)	Moisture, per cent. by weight, max.	3.0	3.0
(iv)	Grit, per cent. by weight, max.	0.2	1.5
(v)	*Colour reflectance to blue light of wave length 5040 A°, per cent., min.	80	75
(vi)	Total iron (as Fe), per cent. by weight max.	0.35	0.5

*This requirement shall not be obligatory for the material used only for sizing purposes.

The Azam Jahi and Osmanshahi Mills Limited, Hyderabad; the Edward Textile Mills, Bombay; the Indian United Mills, Bombay; the Orissa Textile Mills, Cuttack; the Indore Malwa United Mills, Indore; the Swadeshi Cotton Mills, Kanpur; and the Kesoram Cotton Mills, Calcutta, were some of the important consumers of china-clay for textile industry in 1960. The specifications of china-clay in general are as follows:

(a) China-clay should be white in colour, (b) it should not have grit, but upto 0.5 per cent. may be tolerable in some cases, (c) moisture content should not exceed three per cent. and (d) it should be free from iron, carbonate and organic matter.

Oil cloth.—Clay, for use in the manufacture of oil cloth, should, 'slake' easily to thin cream without leaving lumps, be free from grit, have a good white colour and have a relatively low oil absorption.

Paper industry.—The paper industry employs various grades of china-clay, according to the quality of finished product. The whiteness, fineness, freedom from grit or micaceous impurity determine the suitability of clay for use in the manufacture of high grade paper. Ordinary clay free from grit may be used for the manufacture of newsprint and high quality brown paper.

The Rohtas Industries Ltd., Dalmianagar; the Bengal Paper Mills Co. Ltd., Calcutta; and the Titaghur Paper Mills Co. Ltd., Calcutta are the important consumers of china-clay, in paper industry. Their specifications are as follows:

Rohtas Industries Ltd., Dalmianagar: Less than two per cent. grit in 325 mesh and of very white colour.

Bengal Paper Mills Co. Limited, Calcutta: Should pass through 200 mesh, and have brightness of about 70 G. E.

Titaghur Paper Mills Ltd., Calcutta: Bright white colour, grit not more than one per cent. suspension good, moisture preferably not more than three per cent.

Rubber industry.—In rubber industry, china-clay is used as re-inforcing agent and as filler. For this, china-clay must be free from grit and sandy particles and should be soft and of white colour.

The Indian Standards Institution has laid down the specifications for china-clay of the above two grades for the rubber industry (IS; 505-1958) as given in Table 8 below;

TABLE 8

Sl. No.	Characteristics	Requirements	
		Grade I	Grade II
(i)	Screening residue, per cent. by weight retained on seive 4 (aperture 44 microns)–max.	0.25	0 .5
(ii)	Particle size grading of material passing through IS sieve 4 : Larger than 20	Nil	—
	Between 10 and 20 per cent. by weight, max.	5	—
	Between 2 and 10 per cent. by weight, max.	55	—
	Below 2 per cent. by weight, min.	40	—
(iii)	Moisture, per cent. by weight max.	0.75	1.0
(iv)	Loss on ignition (other than moisture), per cent.	11–14	11–14
(v)	Iron (as Fe_2O_3), per cent. by weight, max.	1.0	1.0
(vi)	Matter insoluble in concentrated hydrochloric acid, per cent.	95	95
(vii)	Copper (Cu), per cent. by weight, max.	.005	0.01
(viii)	Manganese (Mn), per cent. by weight, max.	0.01	0.01
(ix)	Alumina (Al_2O_3), per cent. by weight, min.	30.0	—
(x)	Matter soluble in water, per cent. by weight, max.	0.1	0.1
(xi)	Specific gravity at 27°C., max.	2.5–2.8	2.5–2.8
(xii)	pH (electrometric)	4.5–6	4.5–6
(xiii)	Oil absorption (moisture free), M1 per 100 gms.	30–35	25–30

Occurrences

In West Bengal, china-clay is found associated with rocks of various ages from the Archaeans to the Tertiaries. It is found in the granites and pegmatites, within the phyllites of the Iron-Ore series, within phyllites, mica-schists and anorthosites, within the Daling slates, as a bedded deposit in the Raniganj coalfield, within the Tertiary sandstones and in the underlying laterites.

PURULIA DISTRICT

Mehta (1948) found two types of china-clay in the district—one associated with the granitic rocks and the other with the phyllites of the Iron-Ore series.

(A) *Deposits occurring in the granitic rocks*

(1) *Dhatara* (23°37′ : 86°43′) : The clay occurs in finegrained soda granite in the main granite-gneiss, about a few hundred

metres west of the village Dhatara, which is about 10 km. west of the Ramkanali railway station. According to Mehta, china-clay has been formed by the action of meteoric water on soda granite, which has been softened to a depth varying from 6 m. to 7.6 m. The clay has been derived from the decomposition of the felspars. The soil mantle has a thickness of 1.8 to 2.4 m., sometimes increasing upto six metres. The tailings from washing show abundant felspar grains. Three bulk samples of crude clay, on washing, have shown 6.75, 9.16 and 15.5 per cent. of clay.

(2) *Kalajhor* (23°27′ : 86°35′) ; A number of small pockets of china clay occur south of Kalajhor, between Kalajhor and Kalaboni, at a distance of about 19 km. from the Adra railway station. Clay occurs as small lenticular bodies varying in length from a few centimetres to six metres, having a maximum width of 4.6 m. About six of these patches are well defined and these contain an appreciable percentage of clay in the crude rock. Clay continues upto a depth of six metres in one quarry. A sample from about 1.5 km. north of Kalaboni yielded 21.5 per cent. of clay.

(3) *Mahatamarra* (23°25′:85°55′) : The clay deposit is about eight kilometres from the Jhalda railway station, and thence it is connected by a motorable road. The country rock is a granite-gneiss forming typical dome shaped hills. The clay exposure covers an area of approximatly 700 sq.km. It occurs either on the surface or under a thin cover of soil, upto a depth of about six meters. A washed sample yielded 70.5 per cent. of clay.

Clay occurrences near Taldih (23°24′:84°56′), about 1.5 km. east of the above deposit, and near Tundi (23°59′:86°02′) are uneconomic.

(4) *Rangamati* (23°23′:86°50′) : A good quality kaolin deposit about 1.5 m. thick, under a soil cover of about 4.5 m. occurs near the Rangamati village.

(B) *Deposits occurring in the Iron-Ore series.*

(1) *Associated with the Chaibasa Stage.*

These clay deposits are situated in the vicinity of the thrust zone between the intrusive granite and the Iron-Ore series. These lenticular clay bodies associated with phyllite have been formed by hydrothermal alteration connected with the granite intrusions to the north.

Khariduara (Balarampur) (22°59 :86°38') : The clay deposit occurs along the northern slope of the Thakur Dungri hill about 800 m. south of the village and about eight kilometres south of Manbazar. Clay occurs as lenticular bodies in phyllites and quartzites for a length of about 1.5 km. These lenticular bodies vary in length from 1 to 183 m. or even more, in width from 60 cm. to 30.5 m. and in depth for about 7.6 m. or more. The clay has a yellow cherty appearance at the outcrop, but gives shining white surface when broken. Two samples of crude clay when washed yielded 29.57 per cent. and 37 per cent. of clay. This clay is used as paper filler.

Sialdanga (22°57' : 86°41') : Kaolinised phyllite, about 200 m. long 61 m. wide and 15 m. or more deep, occurs in the loop of the Jone *nala* about 400 m. west of Sialdanga. The rock is of light blue colour, and does not contain much sericite. A sample on washing yielded 56 75 per cent. of clay, but the residue was still rich in kaolinite. A large amount of clay can be obtained from the rock, by keeping it soaked in water, and then crushing and washing it.

(2) *Iron-Ore Stage.*

Clays are found within greyish chlorite phyllites striking E.S.E.-W.N.W., in practically vertical bands south of a prominent patch of epidiorite and hornblende schist belonging to the Dalma lavas. These are thought to have been formed by the hydrothermal alteration of phyllites by the emanations from the lavas (Mehta, 1948).

Dandudih (22°59' : 86°33') and *Tamakhan* (22°59' : 86°36') : China-clay associated with schists, occurs near Dandudih and Tamakhan in the vicinity of an extensive fault zone in the southern part of the district (Dey, 1937).

TABLE 9.

Analysis of kaolin

	Khari-duara (Per cent.)	Sial-danga (Per cent.)	Raja-basa (Per cent.)	Meg-daha (Per cent.)	Mahata-marra (Per cent.)	Dhatara (Washed) (Per cent.)	Kala-jhor (Per cent.)
SiO_2	65.16	76.52	73.28	67.18	55.20	44.00	52.44
Al_2O_3	20.03	14.20	15.87	22.01	20.48	37.40	28.20
Fe_2O_3	2.00	2.40	1.60	3.39	6.40	2.40	2.40
MgO	0.72	1.74	0.85	0.94	1.48	1.01	1.45
CaO	Trace	0.25	1.01	Trace	Trace	Trace	4.72
TiO_2	2.17	Trace	0.71	1.20	5.32	Trace	Trace
SO_3	0.55	Trace	0.64	0.56	0.73	.082	Trace
Loss on Ignition	7.80	3.08	5.98	4.62	10.28	14.18	9.84
Total	98.43	98.19	99.94	99.90	99.89	99.81	99.05

TABLE 10.

Refractory and other tests of washed clays (Mehta, 1948).

Samples from	Plasticity	Fusibility	Shrinkage (Linear) per cent.	Colour after firing
1. Khariduara (Thakur Dungri)	Medium	Does not fuse	5	White
2. Khariduara	,,	Fuses	—	—
3. Sialdanga	Poor	Does not fuse	5	Cream
4. Rajabasa	Medium	,,	5	Grey
5. Megdaha	,,	,,	2.5	,,
6. Mahatamarra	,,	,,	5	Pinkish
7. Dhatara	,,	,,	5	White
8. Dhatara	,,	,,	5	Greyish white and grey
9. Kalajhor	,,	,,	10	Grey

Reserves of clay (Mehta, 1948).

Deposits	Reserves (in tonnes)	Percentage of clay
1. Dhatara	825,000	10
2. Kalajhor	610	20
3. Mahatamarra	5,080	70
4. Khariduara	54,864	30
5. Sialdanga	134,112	60
6. Rajabasa	1,016	60
7. Megdaha	28,448	20
Total	1,049,130	(Approximately one million tonnes)

The actual reserves at Megdaha and Sialdanga may be some what more than what have been shown.

Clay varies widely in chemical and physical properties from place to place. Mehta (1948) observes that the clay occurrences near Kalajhor, Rajabasa and Mahatamarra are too small to be of commercial importance. The clay deposits near Dhatara, Khariduara, Sialdanga and Megdaha are of good quality and have fairly large reserves.

A quantity of 779 tonnes of china clay valued at Rs. 8,000 was produced from the Purulia district during 1959.

Bankura District

A number of good deposits of china-clay have been described from this district. As early as 1842, Homfray (cited by La Touche, 1918, p. 284) described a white porcelain clay from Malliari (23°28′ : 87°17′), and Ball (1881, p. 112) described a kaolin deposit resulting from the decomposition of felspar porphyry from a place 11.3 km. south of Raniganj.

These deposits of china-clay occur within latitudes 22°46′ and 23°34′, and longitudes 86°30′ and 87°29′. They occur within the Archaean granites, gneisses, schists, anorthosites and pegmatites and under a lateritic cover either on the Archaeans or on the Tertiary sedimentaries. The latter type occurs in the eastern and north-eastern side of the area.

I. *China-clay deposits associated with the Archaeans*

Hunday (1949-54) reported a number of clay occurrences in the Bankura district. Some of these are included in the Archaeans. Except the Kharidungri-Jhariakocha deposit, which was investigated by the Damodar Valley Corporation. Some of these clay deposits reported by Hunday were later investigated in detail by the Geological Survey of India. (Krishnan, 1958).

Jamsol (22°47′ : 86°30′): Kaolinised pegmatites occur about 400 m. north-west of the Jamsol village.

Kharidungri-Jhariakocha (22°57′ : 86°49′) *areas*: Fairly good deposits of china-clay occur in the form of local enrichment scattered along east-west zone of about three kilometres from north-east of the village Bagjabra (22°57′ : 86°47′) to Jhariakocha through the southern slope of the Kharidungri hill range. The deposits are about 45 km. from the Bankura railway station and are connected with it by a motorable road.

Clays occur as bands in steeply dipping kaolinised sericite-schists (strike east-west) near a major fault zone marked by fault breccia. The clay band near the Bagjabra village attains a width varying from 5 to 11 m. and extends upto a depth of 30 m. Old workings are found at many places in this zone.

The clay near Bagjabra is cream white in colour containing about 60 per cent. grit. On washing it can be rendered suitable

for the pottery industry. The Kharidungri clay in the middle portion of this zone is cream white in colour, hard non-gritty, and phyllitic, having a poor plasticity. It could be used as filler, and with the addition of a suitable bond, it may also be used in the pottery manufacture. It is a high class of china-clay comparable to the Rajmahal clays, excepting that it is less plastic. If properly washed, it becomes suitable for all types of whitewares including Bone-china, but should be blended with a plastic or fat china-clay for increased workability. The Jhariakocha clay in the eastern end of the zone is gritty, medium grade and rich in titania. Lime and iron are also present in appreciable quantities. It is fairly plastic and its shrinkage after firing is high. It is suitable, for the manufacture of earthenware, stoneware, sanitaryware and Low Tension electrical porcelain. By test blending with Kharidungri and Dalombhija (50:50), the product burns white at 1,300°C. and could be used for all types of whitewares.

Bholarkap (23°08′ ; 86°55′) : Kaolin occurs to the north and east of the Bholarkap village which is about 23 km. from Bankura. The clay collected at a depth of 1.2 m. from a place 800 m. north of the village is pale-buff (dull Portland stone) in colour, contains 16 per cent. grit and has fair plasticity and low hardness. It becomes a dirty amber glass when fired at 1,450°C. The clay deposit is not promising. But the sample of clay collected from a depth of 1.2 m. at a place 400 m. east of the village may be suitable for pottery works (C.S.I.R., 1958).

Pabayan (23°22′:87°04′) : Under an overburden of 4.9 to 5.5 m., clay occurs at 1.2 km. N.N.W. of the Pabayan village which is about 5 km. west of the Beliator railway station. The clay with dull pinkish cream colour resembling Portland stone, has medium hardness, high plasticity and it becomes dark beige at 1,450°C. with 12 per cent. total volume shrinkage and fair vitrification. These may be suitable for use in low grade pottery (C.S.I.R, 1958).

Hariharganj (22°49′ : 86°55′)—*Radhamadhabkunjagarh* (22°49′:86°56′)—*Tungi* (22°47′ : 86°55′)—*Raipur* (22°47′ : 86°57′) *areas* : The kaolinised pegmatites occur to the north-west and N.N.W. of the old Fort of the Hariharganj, south of the Panrari village, 800 m. north of Tungi, and in a well section west of it, near Radhamadhabkunjagarh and Mahalbani villages, and in the Kasai river section to the north-east and E.N.E. of the Raipur Police Station.

yield of 48 per cent. from the crude clay. The Dalembhija clay has a high P. C. E., high alumina content, greater plasticity and better workability than the clay at Kharidungri The percentage of iron is low and its refractory property is akin to that with an ideal kaolin composition. This clay could be favourably compared with the best Indian and foreign clays. It is suitable for all types of whitewares including Bone-china. As its firing shrinkage is more, it is desirable to blend this with a clay of lower firing shrinkage. The best result is achieved by blending it with the Kharidungri clay. Both these clays are eminently suitable for the manufacture of chemical porcelain and high tension insulators

Matgoda (22°46′ : 86°54′) : P. K. Chatterjee (Krishnan, 1958) examined the deposit, and found the clay suitable for stoneware and *terra cotta* manufacture. The material withstands firing at 1,300°C.

Tipam (22°57′ : 86°58′) . The clay bands, 60 cm. to 1 m. thick, occur in pockets over an area, 91.4 m. long and 13 7—41.2 m. wide, under 60 cm. to 1.2 m. thick overburden of lateritic soil, near a small *nala* about 400 m. south-east of the Tipam village, which is about 53 km. from Bankura.

The clay is stained, cream coloured, has good plasticity and its colour when fired at 1,250°C. is cream. It appears suitable for use in potteries, but the deposit is small.

Banskanali (22°58′:87°01′) : Small pockets of clay (exposed thickness 60 cm. which extends downwards) in the kaolinised pegmatites are exposed in the *nala* section 400 m. east of the Banskanali village which is about 39 km. from Bankura. A motorable road links this place with Bankura.

The clay is bright cream in colour, has good plasticity; its colour is deep cream when fired at 1,250°C. with 21 per cent. shrinkage. The clay is not very promising.

Kichka (23°00′ : 87°01′) : Occasional pockets of clay usually under lateritic capping occur south of the village Kichka, which is about 34 km. from Bankura.

The clay is pale buff in colour, has high plasticity, and shows high vitrification at 1,250°C. with 17 per cent. shrinkage. Clay is not very promising (C.S.I.R., 1958).

Beriathol (23°30′ : 87°01′)—*Dhatala* (23°29′ ; 86°59′) *Ghanaban* (23°31′ : 87°03′) *areas* : Clay pockets more than 1.52m. in thickness form

after the decomposition of felspars of anorthosite, near the Beriathol village. The deposit is about 16 km. from Raniganj and 6.4 km. north of Kusthalia. The clay is slightly gritty, highly plastic and pale cream to pale buff in colour. It takes a greyish white colour when fired at 1,300°C. with 19-20 per cent. shrinkage and slight vitrification. It may be used as filler, and also in the pottery manufacture after proper treatment.

The Dhatala kaolin is dull white and moderately plastic. It takes light green colour with brown specks when fired at 1,450°C. with 16 per cent. of volume shrinkage and slight vitrifiication. Clays are suitable for low grade pottery (C.S.I.R., 1958) and could be used for the manufacture of stoneware and *terra cotta* (Krishnan, 1958).

Kaolin has also been found in the *nala* section to the west of the Beledanga village (23°29′ : 87°03′), and within the anorthosite exposures north-east of the Kalipur (23°27′ : 87°03′) village.

China-clay occurs to the north and east of the village Ghanaban. The clay is impure and it is not fully kaolinised. It is not promising (C.S.I.R., 1958), but could be used for stoneware and *terra cotta* (Krishnan, 1958).

Jamua (23°33′ ; 87°05′)-*Shyampur (Amlabandh)* (23°32′ ; 87°05′)-*Saragdih* (23°32′ : 87°05′) *areas* : Clay is found 800 m. south of the jamua village across Gaighata *Jhor*, N.N.E. of the Shyampur village and W.S.W. of the Saragdih village near the hairpin bend of a *nala*.

The Jamua-Shyampur clay is milky white, slightly gritty with moderately good plasticity, but completely melts into a dark mass when fired at 1,300°C. The Saragdih clay takes a light grey colour with 20 per cent. volume shrinkage when fired at 1,300°C. and it may find use as filler or in porcelain manufacture, when colour is no bar. But these deposits are small (Krishnan, 1958 ; Ray, *at al.* 1955).

Gorangdih (23°07′ : 87°02′)-*Kharigara* (23°08′ : 87°01′)-*Kalyani* (23°09′ : 87°02′) *Areas* : A clay bed was found exposed, under a 1.2 m. thick laterite capping, for a length of about 31 m. in a *nala* section about 800 m. to the east of the Gorangdih village which is about 16 km. from Bankura. Similar clay under the laterite capping has been found 800 m. N. N. W. of Gopalpur (23°07′ : 87°02′) village. One band of white clay, about 60 cm. thick, under laterite gravels and pebbles, has been reported during digging of a well to

the W. S. W. of the small village north of Kharigara. Clay is also found to the south and S.S.W. of Kalyani village.

The Gorangdih clay is pinkish, hard, fairly plastic and contains about 10 per cent. grit (ferruginous). Fired colour is light drab, and it has high vitrification (highly bloated and deformed) at 1,450°C. This clay is not very promising (C.S.I.R., 1958). The Gopalpur clay is also not very promising (C.S.I.R., 1958). The Kalyani clay is grey, soft and non-gritty. The fired colour is light brown at 1,300°C. with 36 per cent. shrinkage. This clay may find use in stoneware and in the manufacture of *terra cotta*.

Manipur (23°05′ : 87°00′): Clay beds of 1.22-1.52 m. thickness under an overburden of 2.74 to 4 m. occur 800 m. north-east of Manipur village which is about 23 km. from Bankura. Kaolin pits have been noted in an area 188 m. long and 37 m. wide.

The clay is soft, pale white in colour, slightly gritty and highly plastic (percentage of water of plasticity 31.4). The percentage yield from the crude clay is about 58. It takes a pinkish buff colour (light drab) when fired at 1,450°C. with 20 per cent. volume shrinkage. Less gritty variety burns white but the volume shrinkage increases to 36 per cent. The refractory test shows low vitrification (checked and cracked). This clay may be suitable for stoneware (C.S.I.R., 1958) and also it may be used as filler or in porcelain manufacture (Krishnan, 1953 ; Ray *et al.*, 1955). The research in the Bengal Ceramic Institute, Calcutta shows that this clay when blended with the Kharidungri type of clay (50:50) yields a perfectly white buring product suitable for any type of whiteware including porcelain. A composition of 75 per cent. Manipur clay and 25 per cent. Rajmahal or Kharidungri clay yields a fine cream colour when fired at 1,300° to 1,310°C., and it could be used for the manufacture of fine ivory coloured earthenwares.

Siarbada (23°08′ : 87°02′): Clay occurs under an overburden of about one metre of laterite and lateritic pebbles about 400 m. east of the village Siarbada which is about 23 km. from Bankura. Local people use this clay for white washing purposes.

The clay is pale buff, non-gritty, soft and highly plastic. The fired colour is light grey with 36 per cent. shrinkage and shows high vitrification at 1,300°C. It may be suitable for stoneware, *terra cotta* and even for potteries if the colour is no bar.

Tilasuli (23°19′ : 87°10′): An area, about 400 m. long and nearly the same width, to the south and S.S.E. of Tilasuli village shows signs of kaolinisation in pockets under a varying thickness of lateritic overburden. The clay extends beyond three metres in depth at places. The nearest railway station is Beliator which is about five kilometres east of the deposit.

The clay is hard, non-gritty and highly plastic. It is pale pink to pale cream in colour and does not soften at 1,300°C. when it takes a light grey to brick red colour with 12-30 per cent. shrinkage. The test for refractoriness shows fair vitrification with bloating at that temperature. The clay appears suitable for use in pottery (C.S.I.R., 1958) and also for stoneware and *terra cotta* (Krishnan, 1958; Ray, *et al.*, 1955).

Belboni (23°17′ ; 87°09′)—*Kharigara* (23°16′ ; 87°10′) *areas*: Kaolinisation has been noted near the village Kharigara and in the *nala* Section about 1.5 km. west of the village Belboni. The clay is highly pastic, stained and non-gritty. The clay withstands firing at 1,300°C., dan is suitable for stoneware and *terra cotta* (Krishnan, 1958). The washed clay if blended with good china-clay is suitable for making all types of earthenwares and low tension insulators (Ray *et al.*, 1955).

(II) *China-clay deposits associated with the Tertiaries*

A number of clay deposits associated with the Tertiary rocks occur in the Bankura district of West Bengal. Some of these deposits reported by Hunday (Krishnan, 1954) were further investigated by P. K. Chatterjee (Krishnan, 1958). The details of some of these occurrences are given below:

Dhunara (23°16′ : 87°10′)—*Khairkanali* (23°17′30″ ; 87°0?′00″) *areas*: White lithomargic type of clay, with an exposed thickness of 1.22 to 3.2 m., and a laterite capping of 2.13-2.43 m., has been found in the *nala* cutting west of the village Dhunara, which is about three kilometres from Belboni. The greyish clay occurs 400 m. west of the village Khairkanali

The Dhunara clay is dull greyish white with good plasticity. It takes maroon brown colour at 1,250°C. with 14 per cent. shrinkage and fair vitrification. It appears suitable for pottery making. The

Khairkanali clay may be suitable for stoneware and *terra cotta* manufacture (Ray, *et al.*, 1955).

Rampur (23°22′ : 87°12′) : Clay occurs in a sal jungle about 1.6 km. north-east of the village Rampur. Old workings are seen there (Krishnan, 1958).

Ghutgarya (23°26′ : 87°15′) : Small lenses and bands of white clay, 15 cm. to one metre thick, formed of local kaolinisation of felspathic sandstones occur at about 800 m. south-west of the village Ghutgarya which as about 40 km. from the Bankura and 11 km. from Durgapur.

The washed clay has a mixed dull white and pale cream colour with a light pinkish tinge. The clay is hard, and slightly gritty with good plasticity. The fired colour is cream with grey specks at 1,250°C. with 21 per cent. shrinkage and no vitrification. This is suitable for low grade pottery where colour is no bar (C.S.I.R., 1959 ; Ray *et al.*, 1955).

Saharjora (23°24′ : 87°15′) : Clay occurs 400 m. west of the large tank to the north-east end of the village Saharjora which is about 10 km. from Beliator. The clay is of poor quality and is not very promising.

Sonergram (23°25′ : 87°17′) : One clay bed is exposed in a small *nala* 800 m. south-east of the eighth mile—stone on the Barjora-Bankura road about 1.2 km. west of Sonergram which is about 36 km. from Bankura.

The clay is dull white and buff in colour, has a good plasticity, and when fired at 1,250°C. its colour turns grey with brownish tinge with 17 per cent. shrinkage and high vitrification. The clay is suitable for low grade pottery.

Jharia (23°21′ : 87°17′) : Clay beds with an of exposed thickness of 30 cm. and extending downward below a 30 cm. to 3 m. thick lateritic soil cover are found in the *nala* north-east of Jharia which is about four kilometres from Brindabanpur. The clay is of poor quality and may be suitable for red pottery (C.S I.R., 1959).

Kanchanpur (23°23′ : 87°13′)-*Jambedia* (23°23′ : 87°16′) *area* : China-clay has been found at a depth of 2.44 m. in two tanks in the village Kanchanpur about 10 km. north of Beliator and 13 km. south-west of Durgapur Ghat. It is also reported that large quantity of yellowish clay is available further east, near Jambedia on the

Beliator-Durgapur Ghat road, and the industries like tiles, pipes and potteries may utilise these clays.

Bhedua (23°15′ : 87°13′)-*Baidkona* (23°13′ : 87°13′) *area* : Cream coloured clay, with an exposed thickness of 80 cm. to 1.22 m., has been found under a laterite capping of 60 cm. to 1.22 m. thick in the *nala* section south-east of Bhedua. The clay bed is seen continuing downstream upto the north-west of Baidkona village. Beliator is about seven kilometres to the east of it.

The Bhedua clay has high hardness and plasticity, and when fired at 1,300°C. its colour is light ash with 20 per cent. shrinkage. This clay is suitable for porcelain manufacture where colour is no bar. The Baidkona clay has high vitrification at 1,250°C. with deep pearl colour.

Swaragabati (23°17′ : 87°17′) : Clay beds, with exposed thickness 50 cm. and extending downward, have been found in the *nala* section 800 km. E.N E. of the northern Swaragabati which is about four kilometres from Brindabanpur. The clay is of poor quality and may be used for low grade pottery.

Barachatra (23°21′ ; 87°21′) : A thin clay band underlying ferruginous sandstone is exposed in the Sali *nadi* S. S. E. of Barachatra village which is about 2.4 km. from the Hamirhati railway station. The clay is suitable for red pottery

Madhabpur (23°09′ :87°11′) : A clay bed with an exposed thickness of 30 to 60 cm. under is found a cover of laterite and gritty ferruginous sandstone in the *nala* cutting east of the causeway on Bankura-Midnapore road near Madhabpur village which is about 3.6 km. from Ondagram. The clay is suitable for red pottery.

Patalpur (23°10′ : 87°16′)-*Bauridanga* (23°11′ ; 87°15′) area : Clay beds (exposed thickness one to three metres) are found in the *nala* N.N.E. of the Patalpur and north-west of Laharara (23°09′ : 87°17′) which is about seven kilometres from the Ramsagar railway station. Clay beds with an exposed thickness of 1 to 1.22 m have also been found in the *nala* in the jungle N. N. E. of Bauridanga which is about eight kilometres from Ondagram. The clays are of poor quality and may be used in low grade pottery where colour is no bar.

Siara (23°16′ : 87°15′) : A clay bed (exposed thickness 50 to 60 cm.) has been found in the *nala* to the north of Siara village. which is about 10 km. from Ondagram. The clay may be suitable for red pottery,

Pathar (23°16′ : 87°20′) : A clay bed (exposed thickness 50 cm.) under laterite has been found in a tank in the Pathar village.

Agarda (23°04′.87°14′)—*Kumardaha* (23°04′ : 87°15′)-*Mukundapur* (23°04′ : 87°16′) *areas* : Clay beds (exposed thickness two metres) under a lateritic cover of thickness one to one and half metres are found in the *nala* section near the crossing of the Argarda-Bishnupur cart track and in the *nala* about one kilometre east of Agarda village which is about eight kilometres from the Ramsagar railway station. A similar clay bed (exposed thickness 1.22 to 1.83 m.) occurs in the Birai *nadi* section south of the village Kumardaha which is about six kilometres. from Chyl. Clay beds (exposed thickness 1.22 m). have been found in the *nala* north of Mukundapur. The Agarda and Mukundapur clays may be suitable for red pottery, and the Kumardaha clay could be used for stoneware and *terra cotta.*

Teliberis (23°06′ : 87°14′)—*Lalpur* (23°06′ : 87°16′) *area* : Clay beds (exposed thickness 60 cm. to one metre) are found in the *nalas* 800 m. S.S.W. and south-west of Teliberis and south of Lalpur. The clays may be suitable for red pottery.

Chandabila (23°02′ : 87°12′) : A clay bed (of exposed thickness two metres) underlying laterite is seen in the *nala* south-east of Chandabila village.

Dhansimla (23°15′ : 87°28′) : Thin clay bands underlying lateritic and ferruginous sandstone occur in the *nala* in the jungle 800 m. S.S.W. of Dhansimla village which is about 800 m. from Dhansimla railway station. The clay is suitable for red pottery.

Similar clay beds have also been found in the *nalas* to the S.S.W. of *Dhandanga* (23°16′ : 87°15′), S.S.W. of *Kurkuta* (23°06′:87°12′), east of *Rajduha* (23°05′ : 87°11′) and north and north-east of *Kodalia* (23°14′ ; 87°12′) villages. Such Teritary clays also occur near the villages *Kumarpukur* (23°04′ : 87°22′), *Nimaibandh* (23°10′ : 87°26′), *Chaugan* (23°03′ : 87°19′), *Dhangasol* (23°00′ : 87°17′), *Mahduban* (23°05′ : 87°20′), *Bhalka* (22°59′:88°19′), *Majira* (22°59′ : 87°20′), *Katgura* (22°59′ : 87°22′) *Lohawra* (23°09′ : 87°17′) *Beledanga* (23°29′ : 87°03′) *Sahoujora* (23°24′ : 87°15′) and *Kodali* (23°14′:87°13′) Besides the china-clay deposits, the clayey soil of the alluvial country is at places suitable for brick manufacturing, and such brick field exists at *Sonamukhi* (23°17′ : 87°25′).

The Bankura district has good resources of china-clay and some of them like Kharidungri, Dalembhija. Manipur and Tilasuli are

of good quality. Most of these clays after proper washing and blending may be suitable for high class potteries. The Government of West Bengal has a proposal to install a clay washing plant (having a capacity of 305 tonnes of processed clay per month) at a suitable place in the district.

Reserves

So far reserves of only a few deposits have been roughly assessed and the figures are given below—

Deposits	Estimated Reserves (in tonnes)	Percentage of clay
1. Kharidungri	254,000	45
2. Beriathol	321,868	36.5
3. Tilasuli	353,934	75
4. Manipur	590,093	58
5. Siarbada	590,093	—
6. Ghutgarya	41,148	40.7
	2,151,136 or say 2.2 million tonnes.	

TABLE 11

Ultimate analysis per cent. of some Bankura Clays (Ray, 1954).

Clays (washed)	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Alkalis	Loss on ignition
1. Kharidungri	46.98	36.87	0.48	0.46	0.49	0.26	0.88	13.98
(St. Austell) No. 22, English Clay)	46.20	38.00	0.20	1.00	0.30	0.10	1.50	12.40
2. Dalembhija	45.78	37.40	0.53	0.32	1.22	0.43	0.48	13.84
3. Jharikocha	45.90	36.04	2.45	1.14	1.46	Trace	0.19	12.82
4. Raipur-Hariharganj	50.20	32.55	0.78	0.52	1.90	0.65	0.51	12.89
5. Radhamadhab-kunjagarh	44.34	36.92	1.72	1.36	0.71	0.09	0.83	14.02
6. Manipur	44.36	36.82	1.80	2.26	0.41	0.14	0.11	14.10
7. Kharigara	46.01	35.81	1.92	2.33	1.25	0.37	0.89	11.42
8. Tilasuli	54.72	25.34	2.22	3.54	1.09	0.59	0.26	12.24
9. Belboni	59.19	21.05	3.29	3.56	1.07	0.13	0.71	11.00
10. Khirikanali	50.15	31.12	1.28	2.43	1.25	0.68	0.86	12.22
11. Saharjora	59.68	24.67	1.55	3.10	0.69	0.51	0.93	8.81
12. Ghutgarya	51.10	30.87	2.64	1.28	1.72	0.87	0.68	11.84

TABLE 12

Proximate analysis (in parts) of some Bankura clays (Ray, 1954).

	Deposits	Clay Subs.	Felspar	Quartz.	Fe_2O_3	TiO_2	$CaCO_3$	$MgCO_3$	Free Al_2O_3
1.	Kharidungri	90.73	7.73	1.74	0.46	0.48	—	—	—
2.	Dalembhija	91.43	2.83	1.44	0.32	0.53	2.17	0.90	—
3.	Jhariakocha	90.30	1.12	3.19	1.14	2.45	2.60	Trace	—
4.	Raipur–Hariharganj	80.84	3.00	10.76	0.52	0.78	3.38	1.36	—
5.	Radhamadhab–Kunjagarh	88.54	4.90	—	1.36	1.72	1.27	0.19	1.02
6.	Manipur	92.48	0.65	0.93	2.26	1.80	0.73	0.29	—
7.	Kharigara	87.82	5.25	1.79	2.33	1.92	2.23	0.78	—
8.	Tilasuli	63.16	1.51	24.38	3.54	2.22	0.19	1.24	—
9.	Belboni	51.13	4.18	42.02	3.29	3.56	1.90	0.28	—
10.	Khairkanali	76.08	5.07	11.50	2.43	1.28	2.22	1.42	—
11.	Saharjora	59.50	5.78	28.28	3.10	1.55	1.22	1.07	—
12.	Ghutgarya	79.10	2.71	13.17	0.72	1.39	1.69	0.82	—
13.	Beriathol	75.95	4.10	12.20	1.28	2.64	3.06	1.83	—

Nearly two dozen pottery factories in and around Calcutta use china-clay mostly from Bihar, and the annual consumption of this material in West Bengal during 1955 was about 25,400 tonnes. The material was consumed by different industries in the following quantities.

Ceramic industries.	6,096 tonnes.
Textile industries	6,604 "
Paper industries	6,604 "
Rubber industries	6,096 "

The production of china-clay from the Bankura district during 1953 was only 142 tonnes.

BURDWAN DISTRICT

White and cream coloured Tertiary clays occur within the Durgapur beds near Durgapur (23°29′ : 87°18′). These beds crop out in large excavations to the north of the railway station and are also exposed as seams upto several metres in thickness in the locality. The clays are quarried by Messers Burn & Co. and utilised at their Durgapur works for manufacturing bricks and tiles. These clays attain a workable thickness of about 5.5 m. in the main pit to the north of the Durgapur brick works and

about nine metres in the south-eastern excavation. These clays are similar to the Tertiary clays found in the Bānkura district under a variable thickness of laterite cappings (Ball, 1881, cited by La Touche, 1918, p.284; Gee, 1932, p. 62). Extensive clay beds may be found within these Tertiary rocks when detailed prospecting is undertaken.

In addition to these clays, the district is also rich in argillaceous alluvium which produce bricks and tiles by open burning at a number of places in the coal fields. These products, many of which are of inferior quality, supply local needs (Gee, 1932).

Birbhum District

Large deposits of Tertiary clays have been reported from many parts of the district, particularly around Muhammad Bazar (23°59′ : 87°34′). Clay beds 4.57 to 7.62 m. thick and extending to a depth of 15.24 m. or more, occur below a variable thickness of laterite and latertitic gravel in the area. Mehta (1948) examined some of the clay deposits in the Birbhum district as those near Muhammad Bazar. Hunday subsequently investigated some of the clay deposits in 1954 at the instance of West Bengal Govt., occurring near.

(i) Muhammad Bazar (23°59′ : 87°34′)
(ii) Kumarpur (23°59′ : 87°35′)
(iii) Kharia (23°59′ : 87°35′) and
(iv) Dewanganj (24°04′ : 87°35′).

He recognised the Tertiary age of these clays which contain large specimens of dicotyledonous fossil wood. He estimated a reserve of about 960,000 tonnes of clay (836 cu. dm. per tonne) in the area and also reported that 151,680 tonnes of clay have been locked up below the community project scheme township Recently, the Geological Survey of India have further carried-out detailed prospecting of some of these clay deposits by drilling, and over 20 deposits of clay have been located. A total of about 241 m. has been drilled by hand-auger drilling during 1958-59 and 1960-61 field seasons. The details of the deposits are given below—

(1) *Muhammad Bazar* (23°59′ : 87°34′) *area.*—It is about 13 km. north-west of the Sainthia railway station of the Eastern Railways and about same distance from the Suri railway station and

connected with both the places by motorable roads. Extensive deposit of clay occurs here under a variable thickness of laterite and lateritic gravels followed by iron-stained white clay and then white clay of variable thickness. This is regarded as lithomarge type of lateritic clay formed from weathering of rocks under tropical conditions, and the composition of these clays sometimes approaches to kaolin. Rest of the clays are high in alumina and low in silica. Mehta (1948) examined these clays and a pit dug (800 m.) south-east of Muhammad Bazar I.B. showed laterite 1.83 m. white clay stained with iron-oxide 1.52 m., white clay 3 m. and white clay stained with iron-oxide one metre. The clay is mica free, and quartz forms the main bulk of the grit. The existing quarry near the above place has a section at a depth of three to four metres which shows the following sequence—

Laterite capping	61 cm. to 1 m.
Gritty ferruginous sandstone . . .	1 to 1.22 m.
Coarse yellowish felspathic sandstone	61 cm. to 2.13 m.
Clay beds	60 cm. to 1.5 m.

According to reports of the C.S.I.R. (1959), the clay is pale-white with pinkish tinge with 40 per cent. yield from crude clay. This is one of the best plastic clay having water of plasticity at 34.6 per cent., drying shrinkage at 110°-145°C., fired shrinkage at 10-21 per cent. at 1,250°C. and also 19 per cent. at 1,450°C. The colour after firing is mixed pale cream and light grey at 1,250°C. The clay is suitable for use in pottery and refractories. This clay mixed with 50 per cent. of Kharidungri clay is found suitable for any type of whiteware including porcelain : when blended with 25-30 per cent. of white burning clay, it is suitable as bonding agent in semi-silica bricks, and in the manufacture of saggers when mixed with semi-plastic fire-clays.

The extent of the clay bearing area here is about 526,760 sq. m. with an estimated reserve of 1,410,180 tonnes. This clay is being quarried now for use in the rubber and fire-clay industries.

(2) *Kumarpur* (23°59′ : 87°35′).—The clay deposit is about 1.5 km. south-east of Muhammad Bazar, and has an extension of about four hectares. The mines are being worked by M S. Indian Mineral and Associated Industries Ltd. The clay is found 1.52 to 4.6 m. below the soil and continues upto a depth of 13.3 m. It is

siliceous, ferruginous and mica free. There are a few other quarries in the area covering a total of 29.4 hectares of land. The clay of the area adjoining Mayurakshi sub-canal is the best. The unwashed finely ground (-150 mesh) clay is sold to the Imperial Chemical Industries, and M/S. Indian Oxygen and Acetylene Co. Ltd. Recently, the Geological Survey of India have estimated the reserve of crude clay in this area at 634,640 tonnes down to a depth of nine metres (Roy, 1964).

The clay is fairly plastic, pale cream in colour having 40 to 43 per cent. yield from crude clay. Fired colour at 1,250°C. is cream with 17-21 per cent. shrinkage and slight to fair vitrification. The deposit is promising and suitable for pottery and refractories (C.S.I.R., 1959). The clay, though high in iron and titania, may be used in the manufacture of attractive ivory coloured earthenwares, low and medium tension insulators and medium heat duty refractories. Though its fired shrinkage is high, it can be used for whiteware (porcelain, fire earthenwares, stoneware, sanitaryware etc.) if blended with Kharidungri type of clays (60:40) (Ray, 1954).

The clay samples from Chowki Suri Plot No. 934 to the south of Kumarpur Temple, from east of Santhal village, which is 400 m. S. S. W. of Kumarpur and from the Community Project Town, 1.6 km. east of Muhammad Bazar have practically similar physical properties.

(3) *Kharia* (23°59′ : 87°36′).—The quarries are about 2.5 km. south-east of Muhammad Bazar. The clay extends for six metres in depth in this area. The crude clay is white and mica free, and is being sold to M/S. Burn & Co. Ltd., Raniganj.

The clay is fairly plastic, dull white to pinkish cream in colour having 32 per cent. yield from crude clay. When fired at 1,250°C., its colour is pale cream with 17-19 per cent. shrinkage and slight vitrification. The clay deposit is economic to work and is suitable for use in pottery and refractories (C.S.I.R., 1959). The clay contains high amount of titania and is more ferruginous than Kumarpur variety. Blended with 25-30 per cent. of white burning clay of lower firing shrinkage, it may be used for ivory coloured earthenwares, and blended with 50 per cent. Kharidungri type of clays it is suitable for all types of whitewares, saggers and medium heat duty refractories.

(4) *Rajuadharpur-Anargora.*—Clay occurs 1.8 to 2.4 m. below the surface adjoining the Mayurakshi sub-canal, about 1.6 km. south of

Muhammad Bazar. The clay is more ferruginous, but fairly plastic. The yield from the crude clay is 35 per cent. Fired colour is light cream at 1,300°C with 18 per cent. shrinkage and slight sintering. The clay bearing area around Muhammad Bazar covers nearly 5.2 sq. km. with the clay extending to 15.3 m. in depth.

The Bengal Ceramic Institute has found that these clays besides being used in ceramics, may also be utilised in rubber, paint, textile and chemical industries either as sizing materials or as diluents or fillers. The Imperial Chemical Industries are using crude finely ground (—150 mesh) Kumarpur clay as a filler for the manufacture of insecticide. The high plasticity of the clays are advantageous in the textile industries. The Kharia and Kumarpur clays are best suited for paper industry due to their pure white colour.

(5) *Dewanganj* (24°04′:87°36′) : Clay occurs in kaolinised Gondwana sandstones about 1.6 km. S. S. E. of Dewanganj which is about 18.5 km. from Mallarpur by motorable road.

The clay is dull cream in colour, moderately plastic and shows 10 per cent. shrinkage, 17 per cent. absorption and white colour with no vitrification at 1,250°C. The clay deposit is economic and suitable for whiteware and refractories.

(6) *Deocha* (24°02′:87°35′) : Clay occurs in kaolinised Gondwana sandstones at Deocha which is about 19 km. from Mallarpur by motorable road.

The clay is dull cream in colour, moderately plastic and shows 10 per cent. shrinkage, 17 per cent. absorption and white colour with no vitrification at 1,250°C. The clay is promising and suitable for whiteware and refractories.

(7) *Chak Nurai* (24°12′:87°44′) : White clay has been reported from south of Chak Nurai village. The material is lithomargic and lies under a thin capping of laterite. It is dirty white in colour and fairly plastic. The clay briquette is infusible at 1,400°C, but shows numerous cracks. Fired colour is brown with 28 per cent. volume shrinkage. The reserves are reported to be considerable.

A quantity of 560 tonnes of clay valued at Rs. 5,000 was produced from the Birbhum district during 1959.

TABLE 12

Ultimate analysis (in per cent.) *of some of the Muhammad Bazar Clays* (Ray, 1954)

Localities	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alkalies	Loss on ignition
1. Muhammad Bazar (Proper)	44.31	36.97	2.11	0.80	0.22	0.26	0.90	14.34
2. Kumarpur (C.S. Plot No. 1409,	43.67	35.23	1.30	3.12	1.37	0.92	0.61	13.78
3. Kumarpur (C.S. Plot No. 934)	46.23	32.70	3.03	0.87	2.21	0.64	0.48	14.84
4. Kharia	43.72	35.12	2.30	3.84	0.64	0.11	0.62	13.61
5. Rajyadharpur-Anaggora	44.20	35.15	2.50	2.93	0.88	0.25	0.50	13.61

TABLE 13

Proximate analysis (in parts) (Ray, 1954).

Localities	Clay subs.	Spar	Quartz	Fe_2O_3	TiO_2	$CaCO_3$	$MgCO_3$
1. Muhammad Bazar (proper)	84.46	12.57	1.16	2.11	—	—	—
2. Kumarpur (C.S. Plot No. 1409)	87.02	3.60	0.88	1.30	3.12	2.44	1.93
3. Kumarpur (C.S. Plot No. 934)	81.09	2.83	6.69	3.03	0.87	2.15	1.34
4. Kharia	86·81	3·66	0·99	2·30	3·84	1·14	0·23
5. Rajyadharpur-Anargora	87·22	2·95	1·74	2·50	2·93	1·56	0·53

MIDNAPUR DISTRICT

Kaolin and white clays associated with the Archaeans and the Tertiary sedimentaries are found at different places in the district. A few of the important localities are described below :—

(1) *Kadamdiha* (22°40′ : 86°40′).—White clay is found north of the village Kadamdiha which is about 13 km. north-west of Belpahari.

(2) *Katachua* (22°37′ : 86°41′).—White clay occurs 800 m. north-west of Katachua village which is about eight kilometres E.S.E. of Belpahari.

(3) *Thakurpahari* (22°37′ : 86°42′).—Considerable reserves of good quality of ochre and china-clay, consisting mainly of kaolinite and illite, occur near Thakurpahari (Chakravarty, 1960).

(4) *Jarma* (22°45′ : 86°41′).

(5) *Katachua* (22°37′ : 86°41′).

A total quantity of 662 tonnes of clay valued at Rs. 6,000 was produced from this district during 1959.

DARJEELING AND JALPAIGURI DISTRICTS

Occurrences of light brown plastic clays and white clays formed by the decomposition of the Darjeeling gneisses and Daling slates have been found at many places in the district. One such clay occurrence in Daling slates has been found near the right bank of the stream at the debouchure of the Sakkam river. Pockets and bands of kaolin in the kaolinised pegmatites traversing the Darjeeling gneisses are also known to occur at several places in the district. Mallet (1882, p. 58) described a bed of kaolin, about two metres thick, from near the Hospital at Darjeeling. A sample of this clay when tested, fused, to a transparent white enamel. These clay deposits are uneconomic. Clays are also reported from some parts of the Jalpaiguri district. The ultimate and proximate analysis of the Jalpaiguri clays are given below (Ray, 1954, p. 255).

Ultimate analysis (per cent.) (unwashed samples)		*Proximate analysis (in parts)*	
SiO_2	72.35	Clay substance	43.7
Al_2O_3	20.55	Spar	7.9
Fe_2O_3	0.46	Quartz	47.4
TiO_2	0.34	Fe_2O_3	0.46
CaO	1.23	TiO_2	0.34
MgO	0.68	$CaCO_3$	2.19
Alkalis	1.44	$MgCO_3$	1.43
Ignition Loss. . . .	3.25		

Burnt colour is white and no sintering absent at 13,110°C,

Statistics

China clay is finding increased in consumption in the different industries in India. Ceramics, rubber and textile industries consumed 152,000 tonnes of it during 1957. The estimated consumption by the end of the Third Five Year Plan will be about 914,000 tonnes. The production of it in India is quite adequate to meet her internal needs, and some of these clays could also be exported. During 1959, 307 tonnes of china clay valued at Rs. 73,000 were exported to Pakistan, Ceylon and Czechoslovakia. The production of china clay in West Bengal and the total Indian output for the following years are given below ;

	West Bengal		*India*	
Year	Quantity (in tonnes)	Value (in Rs.)	Quantity (in tonnes)	Value (in Rs.)
1957	102	1,000	183,409	—
1958	—	—	165,059	2,448,000
1959	1961	19,000	277,105 (R)	3,666,000
1960	39,837	141,000	352,783	4,892,000
1961	47,218	337,000	376,895 (R)	4,477,000
1962	47,026	327,000	384,377	4,529,000

Fire-clay

Fire-clays are sedimentary or residue clays, grey, blue or black in colour and occur mainly in association with coal measures. They are either siliceous or aluminous and low in iron and alkalis. A good fire-clay is aluminous, plastic, having a high thermal resistance, and does not fuse below 1,600°C in an oxidising atmosphere retaining the shape. The specific gravity varies from 2.6 to 2.7. Kaolinite is the important clay mineral found in them. The refractory nature is due to the formation of mullite ($3\,AL_2\,O_3$, $2\,SiO_2$). Alumina varies from 22 to 35 per cent.

Fire-clays, like refractory clays, can be graded into three sub-divisions:-

(a) High grade fire-clays . . Softening above 1,750°C

(b) Medium grade fire-clays . . Softening between 1,650°C and 1,750°C.

(c) Low grade fire-clays . . Softening between 1,500°C and 1,650°C.

West Bengal is the third largest producer of fire-clay in the country and is ranked in this respect only after Bihar and Madhya Pradesh.

Raniganj Coalfield

Fire-clays occur as seams like coal seams, sometimes maintaining constant thickness over a wide area, within Barakar stage. These fire-clays are mostly carbonaceous and occur above, below and within the coal seams, and sometimes as separate bands in the sandstone sequence.

Gee (1932, p.295) has discribed the following principal fire-clay bearing areas in the coalfields. These are (i) outcrops of the Garphalbari-Dahibari grits and coal measures to the north and south of the Kudia *nala*, (ii) equivalent rocks south-east of Damagaria,

(iii) lower measures to the Radhaballavpur-Shamdi-Pahargora area, (iv) Ramdhara-Kantapahari area, (v) Garh Dhemo-Churulia area, (vi) the lower Barakar outcrops of the Trans-Ajay area.

Mehta (1948, pp. 103-111) has described the following fire-clay deposits in the Raniganj coalfield:-

(1) *Ramnagar-Salanpur area*: A fire-clay seam, 61 cm. to 1.83 m. thick occurs west of Damagaria about 4.9 m. below No.II seam. Three seams, 1.83 m., 1 m., and 1.83 m. thick, occur near the crossing of Phulberia and Banbirdih sidings north-east of Salanpur. A fire-clay band, 1 to 1.22 m. thick, occurs consistently on the top of the No. II coal seam north-east of Salanpur upto Alkusha.

(2) *Samdih-Pahargora area*: There are two fire-clay seams, with thicknesses 1.83 m. and 1.22 m., near Rangakanali, one seam, 1.67 m., thick, near the hill 179 m., high (reference height ·587) one seam, 2.44 m., further east near Rupnarainpur, and two seams, one metre and 45 cm. thick on the top of the No. II coal seam in Dabor colliery. Three parallel outcrops, 1.83 m., one metre and 2.13 m. thick with a parting of 1.83 m. thick sandstone, occur north of the railway siding north-east of Samdih. Another 2.44 m. thick, seam occurs just north of Samdih and runs along Lalbazar to thick Pahargora in the east. The pahargora area shows only one important seam of fire-clay, 1.52 m. thick, to the north-east of the village.

(3) *Gaurangdih-Churulia area:* Two seams of brownish fire-clay, 30 cm. and one metre thick, occur west of Dayalpur. Two bands, 30 cm. and one metre thick, occur on the top of the No. IV coal seam, and two bands of same thickness occur on the top of the No. II coal seam near Gaurangdih railway station. The lower band continues upto the end of Barakar stage. Two fire-clay seams, 76 cm. and 1.22 m. thick, occur below No. II coal seam to the north of Denkali and a band of one metre thickness in the Churulia area. One seam occurs north of No. II coal seam and has quarries near Gaurangdih railway station. Another one metre thick band occurs near Jamgram and a 45 cm. thick one near railway culvert west of the Churulia railway station.

(4) *Trans-Ajay-Kasta coalfield area:* Occasional fire-clay beds, such as the one occurring near Afzalpur (23°48′:87°07′) are found in the eastern part of the area. The main seams are in the west. The Kasta seam has three fire-clay bands, 61 cm., one metre. and 1.22 m., thick on the top. A fire-clay seam, 76 cm. thick, occurs along

Jarkunri *nala* south of the railway culvert. Two seams, each one metre thick and separated by 1.83 m. of sandstone, are found near Barkuri. Four seams, 61 cm., 2.44 m., 76 cm. and 2.13 m. thick and close to each other, occur west of Sultanpur. Three seams, 1.83 m. to 30 cm. thick, occur near Palasthali railway station, two to the west of the Pariarpur fault, and two, each 61 cm. thick, on the north of Kasta.

Most of the Raniganj fire-clays are plastic, get white to cream colour after firing at 1,200°C. with variable volume shrinkings from 2.5 to 9 per cent. Samples from Phulberia, Gaurangdih and west of Dayalpur are quite refractory and show good colour after firing.

Typical analysis of good quality fire-clays (worked by Messrs. Bird & Co.) are given below (Gee, 1932, p. 296):-

	Gaurangdih (Per cent.)	*Patlabari* (Per cent.)
SiO_2	50.48	53.58
Al_2O_3	35.06	30.88
Fe_2O_3	0.64	0.68
CaO	0.33	0.28
MgO	0.20	0.22
Na_2O	0.04	0-25
K_2O	1.09	1.15
Loss on ignition	12.12	12.98
Total	99.96	100.02

Reserves

Mehta (1948) had estimated an approximate total reserve of fire-clay in the Raniganj coal field at 4,129,532 tonnes down to a depth of 6.1 m., assuming that 25 per cent. of the material has already been worked out. Area-wise reserves of fire-clay excluding the quantity already mined are given below:-

		(in tonnes)
1.	Nirsa Chatti (most of this is in Bihar)	370,166
2.	Ramnagar-Salanpur	276,820
3.	Samdih-Pahargora	792,508
4.	Gaurangdih-Churulia	1,197,329
5.	Trans-Ajay-Kasta area (some part in Bihar)	763,191
		3,400,014

Other occurrences in the Raniganj coalfield

(1) *Hermit's Hut, Panchet Hill* (23°37′:86°47′): A thick bed of fire-clay has been noted upto a depth of 7.62 m. near the Hermit's Hut (579 m. elevation) on the Panchet Hill (Roy, 1938, pp. 209-214).

(2) *Ranimahal, Panchet Hill:* Occurrences of fire-clay have also been found near Kalojor near Ranimahal on Panchet Hill.

(3) *Chaklatabari* (23°30′:86°45′): D.R.S. Mehta and J.M. Master carried out detailed survey of the fire-clay deposits near the village Chaklatabari. The fire-clay is non-plastic and the reserve is estimated at 220,472 tonnes upto 15.24 m. depth.

(4) *Ronei* (23°37′:87°08′); *near Raniganj* : Dark grey carbonaceous clays, approaching impure fire-clay, 1 to 1.22 m. thick, under a laterite capping occur near Ronei village north-east of Raniganj. The clays are on the upper part of the Raniganj measures, and are being worked by Messrs. Burn & Co. for their pottery works at Raniganj. Light grey clays have also been worked in the vicinity of Grand Trunk Road to the north and east of Ronei.

Occurrences outside Raniganj Coalfield

(1) *Jarma* (22°35′:86°41′): Fire-clays occur near Jarma near the Bengal-Bihar border in the Midnapur district.

(2) *Rajabasa* (22°49′:86°24′): An occurrence of fire-clay has been reported from south of Rajabasa in the Purulia district.

The fire-clay resources of the Raniganj coalfield are being utilised by such industries as (1) the Raniganj Pottery Works of Messrs. Burn & Co. at Raniganj; (2) the Bengal Firebrick Works of Messrs. Martin & Co., since amalgamated with M/s Burn & Co. at Kulti, (3) the Kumardubhi fire-clay and Silica Works of M/s Bird & Co. at Kumardhubi, (4) the Reliance Firebrick Works of M/s Andrew Yule & Co. at Chanch; and (5) the Behar Firebricks and Potteries Ltd. of M/s A.C. Banerjee & Co. at Mugma.

Besides these, M/s Martin Burn & Co. uses these fire-clays in their firebrick works at Garphalbari and in tile and brick works at Durgapur.

The expansion of the existing Iron and Steel factories and the establishment of new iron and steel plants in the country have necessitated the establishment of 11 new units for manufacturing firebricks and silica refractories in India during 1956-1959, and

out of these 11 units three are located in West Bengal. The total production of firebricks and silica refrctories in India has gone up from 379,984 tonnes at the end of the First Plan (1956) to over 776,224 tonnes in 1959.

PRODUCTION STATISTICS

Year	West Bengal Quantity (in tonnes)	West Bengal Value (Rs.)	India Quantity (in tonnes)	India Value (Rs.)
1955	15,050		88,891	
1956	36,594	224,000	141,717	
1957	41,508	209,000	166,176	
1958	20,245	116,000	195,332	1,688,000
1959	20,843	91,000	217,528	1,597,0C0
1960	20,983	111,000	257,937	2,165,000
1961	30,928	108,000	285,238	2,417,000
1962	35,424	174,000	337,951	2,886,000

Production in the Birbhum district of West Bengal during 1958—1960.

1958 Quantity (in tonnes)	1958 Value (Rs.)	1959 Quantity (in tonnes)	1959 Value (Rs.)	1960 Quantity (in tonnes)	1960 Value (Rs.)
5,824	32,000	4,882	16,000	25,000	4,398
14,421	84,000	15,961	75,000	86,000	16,585

Next to coal, clay deposits form one of the important mineral resources of West Bengal. The various types of clay deposits found in the State, particularly the more promising ones in the Birbhum, Bankura and Burdwan districts need fuller assessment for their exploitation and proper utilisation. At present, the ceramic industries of the State are mostly dependent on the imported raw materials from other States. The indigenous resources of the State certainly have a prospect to meet the internal demands of the State as well as, when properly developed, to cater the much needed growth of the ceramic and refractory industries of West Bengal.

The National Council of Applied Economic Research in course of Techno-Economic Survey of West Bengal has rightly recommended establishment of two additional whiteware units (each over 1500 tonnes annual capacity) and one sanitaryware unit (over 5,000 tonnes annual capacity) near Suri in the Birbhum district, a

stareware unit near Midnapur town, and a new refractory unit (over 12,000 tonnes capacity near Durgapur in addition to the existing six units in the State) with a total installed capacity of 142, 240 tonnes annually, utilising the clay resources of the State.

The council estimated an investment of Rs. 5,500,000 for the stareware and whiteware units and Rs. 35 millions for the refractory unit and these units, when installed, are likely to give an additional employment to 4,600 persons.

Towards mining and working out of the china-clay deposits of the State, the National Council suggested an investment of Rs. 600,000 (during 1961-71) for production of 101,600 tonnes of china-clay, and an investment of Rs. 900,000 for production of 304,800 tonnes of fire-clay, which was estimated to employ respectively 400 and 1,200 persons for mining.

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CHAPTER—XI

COPPER

General

From ancient times, copper was smelted in considerable quantities in different parts of India, but the industry had died long since. Modern exploitation of Singhbhum copper ores, one of the few workable deposits in India, began about 75 years ago, and has developed into an integrated copper industry including prospecting, mining and smelting. Excepting the one at Maubhander near Ghatsila in Bihar, there is no other copper smelting factory in the country. Although the country's consumption of copper metal in 1960 was 86, 363 tonnes, the internal production during the same year was only 8,910 tonnes and 63,247 tonnes of metal was imported into the country. The anticipated annual consumption of this metal by the end of the Third Five Year Plan (1966) is about 172, 729 tonnes. In keeping with the increased tempo of industrialisation in India, the annual consumption of this metal is increasing at a very rapid rate (1956—40,642 tonnes; and in 1960—86, 360 tonnes). Foreign exchange equivalent to Rs. 240 millions is being drained annually to import this metal.

Localities

Darjeeling District

Occurrences of copper have been reported from the Darjeeling and Jalpaiguri districts since a long time. The smelting industries also flourished in these places in the past. The old workings are seen in many places and the local people proudly possess some of the copper utensils made out of such indigenous copper. The *Pradhan* families of Darjeeling and Sikkim, it is said, had worked several copper mines. Copper-ores were treated in the following manner (1) first, the ore was thoroughly ground and washed, (2) it was smelted with charcoal in a primitive furnace, so as to form a *regulus*, the slag being removed at intervals by cooling the surface of the molten mass with a wisp of wet straw, (3) thirdly, the *regulus* was ground and mixed with cow-dung, made into balls, and roasted with free access to air, (4) the roasted powder was then resmelted in the original furnace.

Copper-ores consisting chiefly of chalcopyrite, copper sulphates and cuprite with malachite and associated commonly with iron pyrites occur mostly as disseminations in the Daling schists and slates.

The ores are mostly of a low grade, at times the tenor of ore is marginal with the exception of a few small pay lodes (Banerjee, 1958-61).

(1) *Peshok* (27°04':88°24') : Cambell, in 1854, announced the discovery of copper-ore at Peshok, about 32 km. from Darjeeling, on the road to Kalimpong (27°04' : 88°28'). In 1874, Mallet examined all the known occurrences of the copper-ores in the area. It is sparsely disseminated in quartzose hornblendic schists. Attempts to exploit this deposit during 1870 had failed. The ore analysed 1.36 per cent. copper. Copper mineralisation is also found near the head of the Rongbong stream, west of Peshok.

(2) *Ranihat* (26°51' : 88°21') : Copper mineralisation is found in two places (1) on the bank of the Rani stream, about 1.5 km. above Ranihat, in quartz and hornblende schists associated with iron pyrites : and (2) near the head of the Chochi stream about 1.5 km. north of Ranihat where an ore body, about 45 cm. wide, is proved for over 27 m. down dip. These have been extensively worked in the past.

(3) *Komai* (27°01' : 88°51') : Copper lodes, 60 cm. to 1.22 m. in width, are exposed on the left bank of the Mochu stream within Daling slates. According to Sir Henry Hayden, the ore is distributed in fairly large masses. A sample from a prospecting drift yielded on assay 3.5 per cent. copper, and 1 dwt. 8 grains of gold per ton. A picked sample gave as much as 26 per. cent of copper. Dunn (1943) thinks this occurrence as promising.

(4) *Mongphu* (26°58' . 88°28') : The mine situated on the left bank of Tista river near Mongphu was the only one being worked at the time of Mallet's visit in 1874. The lodes occur as lenticles, upto 30 cm. thick, in a thick band of clay-slate. The mineralisation has been traced upto 61 m. along the strike. It is said to contain four per cent. copper and reported to have yielded an annual output of 2,613 kg. of copper metal.

(5) *Tongri Hill* (26°57' : 88°34') : One old mine is situated on the west slope of the hill at an altitude of 762 m. The mine was opened in 1882. The copper lodes are thin, 18-20 cm. thick and may sometimes thin down to 2.6 to 5 cm. These occur in quartzose layers inter-banded with clay-slate and contain a considerable proportion of iron pyrites. One sample on assaying gave 1.5 per cent. copper, and a picked specimen, 6.6 per cent. copper.

(6) *Mahanadi* (26°52' : 88°25') : There is an old mine here. The

ore occurs in stringers and small clusters in hornblende-schist and chlorite schist of the Dalings. The width of the zone is about 60 cm. T. K. Kurien (Roy, 1964) has reported traces of malachite along the fracture and joint planes of quartzites at 1·6 km. east of Mahanadi.

(7) *Chel river* (26°58′ ; 88°46′) : A lode of ore, 10 to 30 cm. thick, is stated to be exposed in the bed of Chel river.

(8) *Kalimpong* (27°04′ : 83°33′) : An old mine is situated about 3.2 km. north-east of old Kalimpong station. The mineralistation is in irregular quartz veins and bands of very hard quartzite. The proportion of the ore is also very small. Mining was abandoned on account of the hard nature of the rock.

(9) *Mangwa* (27°03′ : 88°28′) : Only traces of copper in the Daling rocks have been found near Mangwa.

(10) *Pankhabari* (26°50′ : 88°20′) : Traces of copper-ore are found in hornblendes-cihst in this area.

(11) *Gayabari* (26°52′ : 88°19) : Trace of copper-ore have been found in the Daling quartzites near Gayabari.

(12) *Yangmakung* (26°55′ : 88°29′) : Mineralised shales with pyrites and small amounts of chalcopyrite are exposed on the side of a hill above the Yangmakung village near Pankhabari (26°50′ : 88°16′).

(13) *Ryiang* (27°00′ : 88°33′) : A trial drift here showed clay slate with interbanded layers of quartzite containing small quantities of copper pyrites.

(14) *Samthar* (26°58′:88°34′) : Thin lenticular veins of quartz containing copper and iron pyrites have been exposed in a landslip in a ravine joining the Lish river, to the south of the village.

According to Stefanski (1918), there are two distinct copper belts in the Kalimpong sub-division. The first starts in the Nazeok forest division, in the tributaries of the Tista, as well as in the Tista itself, extending towards the Rilli river south-east of Ryiang and then further up at Pashok, at a place 3.2 km. north-east of Kalimpong and then to Rangpo and further on to Sikkim. The second copper belt starts from Yongri and passes through Samthar *Khas Mahal* and then it is mostly covered by a *nappe* and extends onward into Sikkim. Stefanski reports that a sample of copper vein (0.15 to 0.76 m. thick) from Rangpo showed copper content 2.45 per cent. and iron 40.5 per cent. He further states that the average minimum copper content

in the ores from Kalimpong and Sikkim will range from 2.5 to 3 per cent., and suggests that the copper deposits at Yongri, Samthar and Nazeok (with 7.8 per cent. copper), east of Mangpo can be economically mined and locally smelted with the development of transport facilities. The other occurrences such as in the Gorubathan sub-division and near the Chel river etc., according to him, are of no economic value.

Jalpaiguri District

(1) *Buxa* (26°45′:89°38′) : Copper pyrites associated with iron pyrites have been found in quartzose layers in a greenish slate at a place on the hill side about 800 m. west of Buxa.

(2) *Gaopata* (26°46′:89°34′) : Occurrences of pyrites and chalcopyrite are reported from the Jainti quartzites and also from Gaopata (West, 1950, p. 117). The quartz vein which is about 9.1 m. thick and intrusive within the Daling slates and quartzites is mineralised with copper sulphides along a shear zone. The deposit appears to be in the shape of a pocket, and the ore minerals occur in the form of veinlets (4 mm. thick). The quartz also carries lenses of malachite and azurite. The gossan extends upto a depth of 15.2 m. A representative sample of this ore showed on analysis, 1.98 per cent. copper, 3.5 per cent. iron, and 2.41 per cent. sulphur. A thorough prospecting of this deposit is necessary in order to prove its economic prospects.

Purulia District

Traces of copper mineral were occasionally noted in the Archaean rocks in the western part of the State.

(1) *Punda* (22°59′:86°40′) : Ball (1870, p. 76) found ancient excavations for copper near Punda, in which the only sign of copper mineralisation is the encrustations of carbonates on the schists and quartz debris around the old workings.

(2) *Kalyanpur* (23°02′:86°03′) : Similar traces of copper minerals were noted by Ball (1870, p. 76) at Kalyanpur.

(3) *Hatirangora* (22°53′:86°33′) : An occurrence of copper-ore is reported from near Hatirangora. Messrs. Khanna & Co. of Daltonganj worked the deposit for sometime. An analysis of a grab sample showed 16.21 per cent. copper, but according to D. K. Chandra (West, 1945, p. 659) the deposit is not of much economic importance.

(4) *Kantagora* (22°58′:86°42′) : and (5) *Tamakhan* (22°59′:86°36′) :

Copper mineralisation has been recorded from Kantagora and Tamakhan in the Purulia district. These deposits were worked during 1944, and only 15 tonnes of ore were produced. Subsequently the operation was closed (Bhattacharjee, 1956, p. 8)

BANKURA DISTRICT

Traces of malachite and specks of chalcopyrite in association with pyrites occur in the quartz veins, hornblende-schists and amphibolites at the following localities:—

(1) *Damdi* (22°58′:86°46′): Traces of green and blue copper carbonates have been seen in quartz veins, along W.N.W.—E.S.E., intruding the hornblende-schists exposed near the eastern bank of the Kasai river, north-west of the Damdi village (Hunday, 1952).

(2) *Tamakhan* (22°53′:86°45′): Green markings of malachite were noticed on the muscovite-schists and quartz veins about 400 m. south of Tamakhan. According to local information, the area was prospected for copper in the remote past.

(3) *Muktamanipur* (22°57′30″;86°46′00″): Shining specks of chalcopyrite and pyrite and also traces of malachite were noted in the chloritised hornblende-schist and amphibolite to the south and south-west of Muktamanipur village (Hunday, 1952).

(4) *Sarangarh* (22°57′;86°44′); Copper-ore has been reported from the south-west corner of the district. A. K. Dey (1937, p. 121) found traces of copper-ore in the form of chalcopyrite and malachite in phyllites in the stream bed south of Sarangarh.

(5) *Nilgiri* (22°57′:86°43′): Traces ofcopper mineralisation have been noted by A. K. Dey near Nilgiri.

(6) *Narainpur* (22°58′:86°44′): Dey also found traces of mineralisation in the dumps from a prospecting trench along a fault-rock north of Narainpur.

(7) *Khatra* (22°59′:86°52′): Copper mineralisation has also been noted near Khatra.

(8) *Dungrikuli* (22°53′:86°43′): One vein with sulphide minerals has been reported from Dungrikuli.

(9) *Burisal* (22°47′30″:86°42′30″): Veins with sulphide minerals have been reported from Burisal.

(10) *Harangara* (22°42′:86°43′): Veins with sulphide minerals have been reported from Harangara (Chakravarty *et al.*, 1960, p. 26)

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CHAPTER XII

GOLD

From time immemorial, gold has been washed from the alluvial sands along the rivers and streams of southern Chotanagpur and adjacent areas of Purulia, Bankura and Midnapur districts within the watershed of the Subarnarekha (meaning, golden streaked) river and its tributaries, Karkari, Bamni, Kasai, Kumari *nadi* etc. (Dunn, 1941, p. 137 and La Touche, 1918, p. 194).

Even today, villagers close to certain streams recover a small amount of gold by washing the river and stream sands at points which, by experience, they have found to be the most favourable for accumulation of placer gold. This work is more frequently done by women. Gold washing is usually carried out twice a year, just after the rains and during the winter months. Washing is usually carried out in wooden rectangular vats, the smaller ones having a size 61 cm. in length and 37 cm. in width, with a gradual sloping depression towards the centre where it is five centimetres deep. Each vat contains about nine kilograms of sand. Larger vats are also used at times. Sand is collected by simple scraping. About 6.8 to 7.3 kg. of sand are usually taken by the gold washer at a time. While washing the sand with water, a constant oscillatory motion is imparted to separate the heavy minerals from the lighter fractions; the latter are thrown out at regular intervals. From the dried concentrates, the shining gold particles are separated by hand picking. Recovery of gold is rather uncertain and the yield usually poor. A number of tiny particles of gold, worth Re. 1/- to Rs. 3/- in the present market price are claimed to be recovered.

Gold is derived from auriferous quartz veins which generally occur in a zone of schists in the Iron-Ore stage of Dharwar age, underlying the Dalma lava flows. These schists occur on either side of the lavas having an east-west strike, across Ranchi, Singhbhum, Purulia, and the western parts of Bankura and Midnapur districts of Bihar and West Bengal. Here gold is found in the opaque white quartz veins containing blue quartz (Dunn, 1941, p. 139 and Khedkar, 1950, pp. 118 and 121). In fact, gold bearing quartz veins have been worked near Lawa (23°01′ : 86°05′), Ichagarh (23°02′ : 85°57′) and Burudiht (23°02′ : 85°51′) in the Singhbhum district of Bihar, very close to the western border of the Purulia district of West Bengal.

Gold, in association with such heavy minerals as monazite, (?) xenotime, ilmenite, rutile, zircon, magnetite, etc., has been found in the Tertiary pebble beds of West Bengal, Bihar and Orissa. Tertiary gravels and other sedimentary rocks (sandstones and shales), about 45.7 m. to 76.2 m. in thickness, occur in Birbhum, Burdwan, Bankura and Midnapur districts of West Bengal and in adjacent Singhbhum and Mayurbhanj districts of Bihar and Orissa. These beds have been uplifted to a height of about 76 to 107 m. above the present sea-level during the early Tertiary time. These consist of rock materials brought down from the crystalline hinterland which had been levelled down to an elevation ranging from 457 m. to 610 m. These littoral shelf deposits, namely the Tertiary pebble beds, should be thoroughly examined for prospects of gold and other heavy minerals of economic importance, (Khedkar, 1954).

Localities

PURULIA DISTRICT

Gold was found by Ball (1881) in nearly all the streams in the district but the average yield obtained was not very encouraging. The Tutko and Kowari tributaries of the Kasai river are said to be the most productive streams. A small quantity of gold is present in the lead deposit at Beldi (23°03′ ; 86°18′). Gold is associated with glaena in quartz veins within phyllites and schists. Messrs. Mackinnon and Mackenzie extracted about 271 tonnes of ore from this mine, during 1904-5, which yielded 6.8 gms of gold per tonne along with lead and silver (Dunn, 1941, p. 160). Gold was mined in the adjoining area at Mayasara (23°03′ : 86°11′) and Rawa (23°01′ : 86°05′) in Bihar. Alluvial gold is also reported from the Karkari *nadi* and the Subarnarekha river (Chandra, 1944, p. 536).

MIDNAPUR DISTRICT

In 1855, a sample of gold dust from the neighbourhood of Midnapur (22°25′ : 87°24′), probably from the Kasai river, was examined by Piddington.

BANKURA DISTRICT

Hunday (Krishnan, 1954) noted the occurrence of alluvial gold in the heavy mineral residues of the Kasai and Kumari *nadi*, the two principal rivers in the western part of the Bankura district. References of such occurrences of gold in the Kasai river were also made by A. K. Roy in his report of the year 1943. Besides

the river sands referred to above, some of the samples collected by Hunday from a few *nalas* and from near the outskirts of a few villages showed minute traces and occasionally nuggets of gold in the concentrates left after washing. Black sands from the following localities were found to contain traces of gold.

(1) *Ambikanagar* (22°57′ : 86°45′) : East of the confluence of Kasai river and Kumari *nadi* north of Ambikanagar.

(2) *Simli* (22°57′ : 86°47′) : Further downstream in Kasai river to the north-west of Simli.

(3) *Chirkunkanali-Mahespur* (22°55′ : 86°47′) : In the eastern part of the village Chirkunkanali-Mahespur.

(4) *Jorakend* (22°55′ : 86°46′) : In an irrigation canal about 800 m. S.S.W. of Jorakend village.

A few small flakes including a small nugget of gold (weighing about 0·447 grams) were recovered by Hunday (Krishnan, 1954) by washing about 5.4 to 6.4 kg. of black sand.

(5) *Keshra* (22°55′:86°46′) : In Keshra village near the exposure of a small quartz vein intruding muscovite-, and chlorite-schists.

Besides the above, Hunday recorded alluvial gold through washing of sands in the following localities.

(6) *Sindurpur* (22°56′:86°49′), *Satsol* (22°49′:86°45′) and *Barkola* (22°57′:86°47′) : In the Kasai river to the N. N. E. of Sindurpur, north of Satsol, and east of Barkola.

(7) *Khariakocha* (22°55′:86°47′).

(8) *Damodarpur* (22°56′:86°47′) : In the *nala* to the north-east of Damodarpur.

(9) *Chhatardoba* (22°55′:86°46′) : In the *nala* to the west of Chhatardoba.

(10) *Baddi* (22°57′:86°46′) : In the Kumari *nadi* to the north of Baddi.

(11) *Madhupur* (23°02′:86°48′) : The sand in the small *nala* to the west of Madhupur village near Buchudungri hillock (comprise bluish quartzite and hornblende-schist intruded by younger quartz veins) contains gold particles. It is locally reported that gold washing had been carried out at this place for nearly twenty years, and that each person earned Rs 2.00 to Rs 2.50, worth of gold per day, when the market price for gold was Rs. 45.C0 per *tola*.

Numerous gold bearing sands occur along the banks of streams and *nalas* draining the Archaean rocks. These undoubtedly deserve a thorough prospecting for tracing the source rock, which may possibly be quartz veins.

DARJEELING DISTRICT

Presence of 2.1 gms of gold associated with 3.5 per cent. of copper in a sample of copper-ore disseminated in the Daling slates and schists from an adit was reported from Komai, on the left bank of the Mo Chu in the Darjeeling district (Dunn, 1945, p. 48).

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CHAPTER XIII

IRON ORE AND STEEL

The State of West Bengal does not contain any economic deposit of high grade iron-ore; nor is there any record of commercial production of iron-ore in the State within the last decade or so.

The use of iron in India dates back to the Vedic times, and the iron-ores have been worked here for probably 3,000 years or more. The famous Damascus blades for swords are known to have been manufactured from the Indian steel, and were marketed in Iran and Levant. The famous iron pillar in Delhi and similar ones at Dhar and Mount Abu show the glorious history of India's supremacy in iron metallurgy.

Iron-ore deposits are classified into four principal categories in the country. These include (1) Hematite (Fe_2O_3) with (Fe=70%), (2) Magnetite (FeO, Fe_2O_3) (with Fe=72.4%), (3) Siderite ($FeCo_3$) (with Fe=48.2%) and limonite ($2Fe_2O_3$, $3H_2O$) (with Fe=59.8%) and (4) Ferruginous laterite mainly composed of hydrated oxides of iron and aluminium and also containing manganese, titanium, vanadium etc.

Uses : The Iron and Steel industry of the country, as also of the State, uses hematite-ores as the only iron raw material. However, magnetite (for heavy media coal washeries), spathic iron-ore (for generation of hydrogen on a large-scale in the Steam-Iron contact process), micaceous hematite (as a coating for welding rods) and bog iron ores (as purifying material for water gas or producer gas) are also being increasingly demanded for various uses as above.

Occurrences of Iron-ores

Occurrences of iron-ores are reported both from the western and northern districts of the State. Hematite, magnetite and titaniferous iron-ores are found sporadically in the Archaean tracts of Purulia, Midnapur, Bankura, Birbhum and Darjeeling districts; sideritic and limonitic ores in the Ironstone shales (Barren Measures) of the Raniganj coalfield; hematitic quartzite within the Buxa series (Pascoe, 1939) in the Jalpaiguri district; hematitic beds within Siwalik sandstones of the Darjeeling district; lateritic iron-ores in the Purulia, Midnapur, Bankura, Burdwan and Birbhum districts; and magnetic iron-bearing sand in some river beds in

the Purulia district. Lateritic-ores in the altered Rajmahal traps and the clay-ironstones of the Gondwana formations, including those occurring in the Ironstone shales of the Barren Measures of the Raniganj coalfield are the chief sources of ore in the State, but none of these is used now. The rapid expansion of the industry since 1919 has been due to the opening up of vast hematite deposits in southern Singhbhum, Bihar and in the adjacent Keonjhar and Mayurbhanj districts of Orissa.

Iron-ores are reported to occur in different geological formations in the State, as shown below :

(1) Magnetic iron-bearing sands in some river beds in the Purulia district of Recent and sub-Recent origin.

(2) Lateritic iron-ores capping Archaeans, Gondwanas and the Rajmahal traps.

(3) Hematitic beds associated with the Siwaliks (Upper Tertiary) of the Darjeeling foothills.

(4) Thin beds of concretions of ironstone within the intertrappean beds of the Rajmahal hills—Jurassic.

(5) Hematite-quartzite within Buxa series of the Jalpaiguri district—Purana or Gondwana age.

(6) Ironstone-shales of the Barren Measures (Damuda age-Lower Permian) in the Raniganj coalfield.

(7) Magnetite, hematite, titaniferous iron-ores etc., associated with the Archaean rocks.

Purulia District

Small deposits of iron-ore occur near the following localities :

(1) *Tamakhan* (22°59′ : 86°35′).

(2) *Bauch* (22°59′ : 86°40′) : Lodes of hematite are reported from the hill near Bauch. The ore is said to be rich and abundant (La Touche, 1918, p. 241).

(3) *Asanpani* (22°46′ : 86°27′) ;

(4) *Manbazar* (23°03′ : 86°40′) : Titaniferous iron-ore is found at the foot of the hill to the W.N.W. of Manbazar.

(5) *Supur* (23°01′ : 86°52′) : Titaniferous iron-ore is found in quartz veins near Supur.

(6) *Gaurangdih* (23°26′ : 86°46′) : Titaniferous iron-ore (ilmenite) occurs in pegmatites and quartz veins within a radius of 10 km. around Gaurangdih railway station.

(7) *Jhalda* (23°22′ : 86°00′) : Numerous small crystals of magnetic titaniferous iron-ores (maximum diameter 2.6 cm.) occur in the porphyritic grey Jhalda gneiss, and also in the pegmatites traversing the gneiss. Minute crystals of such ores are found within gneisses near Hesla and Baghmundi to the south of Jhalda and at Bansa Pahar near Jhalda. The ores contain ilmenite, hematite, magnetite, rutile, martite and goethite (Guha Sarkar, *et al.* 1959).

(8) *Baroajora* (23°12′ : 86°05′) : Small occurrences of titaniferous iron-ore (mostly ilmenite) are reported in pegmatites exposed along the Turga *nala*, and those near Baroajora.

(9) *Panchet Hill* (23°37′ : 86°45′) : Surface deposits of rounded and polished nodules or lumps of ironstone ranging in size of a pea to huge boulders occur in the eastern flank of the railway siding to Chowrashi (Roy, 1938, pp. 209-214).

Besides these occurrences of little economic importance, magnetic iron sands occur along many stream courses in the Archaean terrain, and these were formerly smelted for iron (Ball, 1881, and Dunn, 1941).

BANKURA DISTRICT

(1) *Biharinath Hill* (23°35′ : 86°57′) : Blanford (1860, p. 193) noted the occurrence of magnetite ores within metamorphic quartzite at about three kilometres west of Tiluri village near Biharinath hill. The ores occur inter-laminated with the quartzite and gneiss, in bands varying in thickness from 7 cm. to 1 m. The debris found on the surface indicates that the band may extend to 24 km. in length. It is reported that these are very pure, and contain 60 to 70 per cent. iron (Gee, 1932, p. 294). Taking an average of 30 cm. thickness, E. J. Jones (1888) (reported by Krishnan, 1954, p. 115-116) calculated that 55,882 tonnes of ore would be available within a depth of 1.5 m. from the surface.

(2) *Porapahar* (22°57 : 86°49′) *Zone* : Sporadic occurrences of brecciated hematite quartzite with local concentrations of hematite are found along and near the major east-west fault zone. According to Ball (1881), it is the faulted junction between the metamorphic

and sub-metamorphic (Dharwarian) rocks. The zone is found to extend from Sabubad (22°57′40″ : 86°55′30″) near Khatra to Basantapur (22°58′ : 86°45′) to the west. The zone extends further to the west near Bauch in the Purulia district. A. Hunday (Krishnan, 1954) visited these deposits and found hematite-quartzite boulders and local concentrations of hematite along the fault zone near Ambikanagar (22°57′ : 86°49′), Barda (22°57′ : 86°46′), Muktamanipur (22°57′ : 86°47′), Tepra (22°57′ : 86°48′), Bagjabra (22°57′ : 86°48′), Kharidungri (22°57′ : 86°48′), Ruparhir (22°57′ : 86°49′), Dedua (22°57′ : 86°51′), Salua Jamda (22°58′ : 86°52′) and Dhargram (22°57° : 86°54′). The ores are said to be rich and abundant. Hunday also reported the following occurrences (3 to 9) :—

(3) *Purnapani* (22°46′ : 86°47°) : Ferruginous bands in the quartz veins and quartz debris in the *nala* section to the east of Purnapani.

(4) *Kuchaipal* (22°45′ : 86°50′) : Similar deposits near the confluence of Bhairabanki *nadi* and the *nala* to the west of Kuchaipal.

(5) *Maula* (22°51′ : 86°45′) : Similar iron-ores from the ridges west and north-west of Maula.

(6) *Pukuria* (22°49′ : 86°50′) : Same type of iron-ores from the ridges north of Pukuria, and west of (7) *Bishanpur* (22°52′ : 86°54′).

(8) *Bagjobra* (22°45′ : 86°52′) : Lateritic iron-ore is found east of Bagjobra village.

(9) *Dahala* (22°57′ : 86°57) : Similar lateritic iron-ore is found east of Dahala.

(10) *Bankura* : Iron-ore deposits from springs were reported by Everest (La Touche, 1918, pp. 237-240) from a locality 6.4 km. south of Bankura. None of these deposits warrant much attention regarding their economic potentialities.

Hunday noticed sporadic occurrences of slag heaps in different parts of the district. These definitely indicate a flourishing trade in iron smelting in these areas in olden days.

(11) *Saltora* (23°33′ : 86°56′) : S. C. Chatterjee (1937) reported a norite dyke at the junction of granite gneiss and anorthosite containing magnetite in association with vanadium and titanium from Saltora area.

MIDNAPUR DISTRICT

Not much is known about the minerals of this district, as the published literature on the geology and economic mineral resources of this district are practically very scanty to draw up a comprehensive account of them. Still, from the general geological set up of the district, it appears that hematite and magnetite ores similar to those found in the Bankura and Purulia districts may be found in the Archaean terrain of the area, and lateritic iron-ore from the extensive laterite area in the eastern and southern part of the district.

A. K. Dey (Fermor, 1935) has reported that certain phyllites and quartzites in the north-western part of the district grade into hematite phyllite and banded hematite quartzites having local enrichment of low grade iron-ores. He has also reported concentration of magnetite crystals in the surface detritus near Jarma (22°35′ : 86°41′) and Dublakona (22°36′ : 86°45′).

There are several small laterite patches in the north-western corner of the district on Archaean terrain near (1) Patpinria Pahar, (2) north of Talaibani, (3) near Dhangikusum, (4) north and north-east of Bhankhabhanga (22°35′:86°41′), and (5) near Sarisabasa (22°38′:86°44′).

Extensive and thick laterite covers are found near Jhargram, Gidni, Kharagpur, and also on the south-western part of the district.

BURDWAN DISTRICT

Two types of iron-ores, namely, (i) clay-ironstones of the Middle Damudas (Ironstone shales or Barren Measures), and (ii) lateritic ores of the eastern part of the Raniganj coalfield, were one time an important source of the large iron industry in Bengal.

The Ironstone shale group has a thickness of about 366 m., and stretches 53 km. east-west covering an area of about 114 sq. km. Sideritic iron-ores, of sedimentary origin, occur in these shales as numerous thin bands, the average may be taken as one part of ore in 20 parts of shale. The sideritic ores are found to have been converted into limonite near the surface. The ore is more abundant in the upper part of the group (Blanford, 1860). According to Hughes (1874, p. 6), 203 million tonnes of ore with iron sesquioxide content ranging from 43 to 65 per cent. would be available in every 2. 6 sq. km. The average iron content of this ore is about 40 to 45 per cent. with high silica (about 15 to 20 per cent.) and alumina (about 5 to 12 per cent.), and high phosphorus (0. 1 to 0. 9 per cent.). The maximum,

minimum and average values for 19 analyses of these ores collected from Kulti, west of Barakar, and from Churulia-Toposi area are given by Gee (1932) in his Memoir on the Raniganj coalfield. Krishnan (1954b,) gives the reserves of this limonitic and spathic ore at 508 million tonnes proved and probable, and 3,032 million tonnes as possible,

Similar hematitic clay-ironstone bands are found within the shales of the middle and upper Barakars, particularly in the eastern part of the coalfield; and to a small extent within the upper Raniganj strata (Gee, 1932, p. 294).

The lateritic ores of the eastern portion of the coalfield are highly siliceous and pass laterally into quartzitic conglomerates (? Tertiary), the pebbles of which are enclosed in a hematitic matrix. These ores do not contain more than 25 per cent. of iron (Gee, 1932, p. 294).

These occurrences do not prove of economic value for commercial exploitation of iron at present. But these may have a small demand from time to time, e. g., a certain amount of soft limonitic ore is used as a desulphuriser in coking and gas plants.

Birbhum District

This district has long been known as an important centre of iron industry in Bengal. In fact, one of the earliest iron industry on modern lines was set up here. The details of these are given by Oldham (1852, pp. 1-34). Blanford (1860) and Hughes (1875) (referred by Ball 1877, p. 243 ; 1881, pp. 366-367).

The ores in this region are derived from different formations: magnetite from the metamorphics near Namgulia ; veins of limonite from the sandstones of the Damuda and Mahadeva series of the Gondwana system ; layers of pisolitic iron-ore and pockets and thin beds of limonite and hematite from the laterite within flows of the Rajmahal trap (of Jurassic age) to the north of the district. Lateritic iron-ore is found capping the Archaeans, Gondwanas, and the Traps on the southern margin of the Rajmahal hills.

According to Hughes (Ball, 1877), there are two or three seams of limonitic ore in the laterite. Analyses of the ores showed that they contained 28 to 59 per cent. iron, an average of 29 samples showing 43 per cent. iron, and 1. 5 per cent. P_2O_5. (La Touche, 1918 ; Krishnan, 1954 a).

DARJEELING DISTRICT

(1) *Sikabar* (27°01′:88°33′) : The iron-ore from which superior quality of iron was produced in the past by the Nepali workers, occurs as a 6. 1 m. thick band in the actinolite-schist and talc-quartz schist of Daling series at Sambalbong about 1. 5 km. E. S. E. of the village Sikabar in the Kulayganj Reserved Forest of the Kalimpong sub-division, and at a place about 60 to 90. m. above the bed of Rer.

The ore is reported to consist of high grade micaceous hematite and octahedrons of magnetite and is free from sulphur and phosphorus. The pure band yielded 71. 50 per cent. iron and the micaceous hematie, 58. 90 per cent. iron (La Touche, 1918). According to Mallet (1875), the deposit is a valuable one and the quantity appears to be considerable. In the river beds of Ranga, Sakam Chu, and Mo Chu, boulders of iron-ores are also reported.

(2) *Lohargarh* (26°47′:88°12′) : Iron-ore varying from ferruginous clay to impure brown hematite occurs within Siwalik sandstones (Tertiary) in the Lohargarh area south-west of Pankhabari. Mallet (1875) noted the maximum thickness of this band as 36. 57 m. and the length of the outcrop 1.6 km. (La Touche, 1918). M. S. Balasundaram (Roy, 1961) noted the thickness as 30. 5 m. and the length of this lenticular ferruginous band about 1. 6 km. It has a brecciated appearance. The ore is of poor quality and contains a maximum of 30 per cent. iron.

JALPAIGURI DISTRICT

(1) *Buxa Bazar* (26°45′:89°34′) : Occurrences of massive hematite-schists and banded hematite quartzite attaining occasionally a thickness of about 15 m. are reported from near Buxa Bazar.

(2) Small sporadic occurrences of locally enriched low grade iron-ore (mostly hematite) in the banded hematite-quartzites associated with slates and quartzites, are reported from north of Raimatong (26°47′:89°31′) and other places in the western part of Buxa Duars.

(3) *Goapata* (26°46′:89°34′) : One sample of this hematite ore from a place (altitude 609.6 m.) about 400 m. west of Goapata village gives on analysis (West, 1950, p. 133) :—

Al_2O_3	4.90%
Fe_2O_3	54.01%
MgO . , . . .	7.68%
CaO , ...	7.64%
Loss	16.32%
Insolubles	9.42%
Total	99.97%

Another sample of a banded hematite slate rock altering to hematite, collected from a hill near the tributary of the Dima river, gave Fe_2O_3 content as 30. 07 per cent.

Iron and Steel Industry in West Bengal

The indigenous iron industry attained a high degree of efficiency in the Birbhum district. It was in 1774 that one Indernarain Sinha applied for the first time to the then Government for a concession to work iron-ore, but no leasewas granted. In 1777, M/s. Motte and Farquhar obtained the right for manufacturing iron in the area west of Burdwan, while at the same time M/s. Sumner and Meatly held mining concessions in certain areas of Birbhum and Panchet. Farquhar relinquished his lease in 1795.

The local iron smelters and the blacksmiths continued their industry into the next century when during 1845, there were about 70 indigenous furnaces producing 2,540 tonnes of iron annually. T. Oldham, the fitst Director of the Geological Survey of India, reported on these iron-ores and iron industries in 1852. He saw furnaces in operation in the villages of Ballia, Narayanpur (24°14' 87°43'), Deocha (24°02':87'37') Dumra (24°06:87°38'), Goanpur (24°03':87°43'), Mallarpur (24°57';87°44'), etc. each furnace having an annual capacity of 35. 6 tonnes.

About the year 1855, Messrs. Mackey & Co. of Calcutta formed the Birbhum Iron Works Co. and erected blast furnaces at Mohammad Bazar (23°59' : 87°38') (Blanford, 1860). By about 1875, Messrs. Burn & Co., also of Calcutta, commenced trial operations in this district, But shortly afterwards discontinued it, presumably because of the unprofitable nature of the project.

The ores were derived from the sandstones of the Damuda (Permian) and Mahadeva (Triassic) series which show veins and lumps of hematite scattered through them, and from the laterite associated with the Rajmahal traps (Jurassic). Certain horizons within the laterite contain seams of good ironstone. Such beds

have been worked near Tamra, Goanpur, Deocha, Seepahadi, Doodhia, Kanda and other places near the southern limit of the Rajmahal trap, and a few kilometres north-east of Mohammadbazar. Analyses show iron content ranging from 28 to 59%, and the average of 29 samples being 43% (Ball, 1877, p. 248).

In the Burdwan district, largely within the Raniganj coalfield, an attempt to exploit iron-ore resources of this region on a modern line started as early as 1839 when Messrs. Jessop & Co. of Calcutta commenced iron smelting at Barakar. In 1874, the Bengal Iron Co. erected two furnaces at Kulti each with a capacity of 20.3 tonnes of pig iron per day, and operated them from the Barakar Iron Works until about 1879 when the works were taken over by the Government and run till 1889. The Bengal Iron & Steel Co., Ltd., called as The Bengal Iron Co., Ltd., in 1919, was established in 1889 (managing agents Messrs. Martin & Co.). This company carried out various improvements and successfully operated five blast furnaces at Kulti, producting 508 tonnes of pig iron per day by 1920, and four batteries (each of 34 ovens) of coke ovens producing 23,370 tonnes of coke per month in 1924 (Gee, 1932, p. 313). Later in 1936, this company was amalgamated with the Indian Iron and Steel Co. The installed capacity of the coke ovens at Kulti during 1952-53 was about 203,210 tonnes of coke per year while the two blast furnaces had a capacity of 254,012 tonnes of pig iron per year, the capacity of the foundry consisting of 1,123 tonnes of pipes, castings, etc. per year. Ferro-manganese containing about 75 per cent. manganese from Indian manganese-ore was also manufactured at the Kulti Works (Krishnan, 1954 a, p. 205).

The Indian Iron and Steel Co., floated under the managing agency of Messrs. Burn & Co. in 1918, erected the works at Hirapur near Asansol. Two modern blast furnaces each of 508 tonnes capacity and two coke oven batteries with 1,016 tonnes per day capacity were installed. By 1930, the capacity of the blast furnaces increased to about 813 tonnes per day, and that of the coke oven plant to 1,625 tonnes of coke per day (Krishnan, 1954 a, p. 206).

In earlier days the company was using limonitic ore from the Ranigang field itself for the Kulti Works, but these were replaced by high grade Singhbhum ores since about 1913.

Apart from the above two IISCO Works, one more Iron and Steel factory has recently been established at Durgapur (23°29′ : 87°18′) in the Burdwan district by the Public Sector.

The Iron and Steel Industry is now well established in West Bengal where at present two major concerns, the IISCO and the Durgapur Steel Works, are producing iron and steel.

The IISCO produced 1.27 million tonnes of pig iron and about 711,233 tonnes of steel during 1950. The power capacity at Hirapur and Kulti were 46,000 kW. and 6,000 kW. respectively during that time when a scheme to put another power plant of 20,000 kW. capacity at Hirapur was laid down. An elaborate expansion scheme was undertaken by the company during 1952-53, and these were completed by the middle of 1959. The Company spent a total amount of 708 millions of rupees (Rs. 670.4 millions for Burnpur, and Rs. 37.6 millions for the Kulti Works) for the expansion during the last ten years from 1952-53 to 1961-62. Out of this total sum spent, the company got a loan of Rs. 212.8 millions from the World Bank (the foreign exchange equivalent of Rs. 150 millions or 31.5 millions dollars to be met from this loan), Rs. 73.5 millions from Govt. of India, Rs. 100 millions as special advance from the Govt. of India, and Rs. 70 millions as new shares issued. The company had to finance the balance Rs. 25.17 crores. A further loan of 19.5 million dollars from the World Bank is being arranged by the Company for the expansion of their collieries.

The production of iron and steel by this Company from 1961 to 1962-63 is given in Table 14 below :

TABLE 14

Year	Pig Iron	All India	Steel	All India
	(tonnes)	(tonnes)	(tonnes)	(tonnes)
1951	675,840	1,830,955	267,476	1,086,915
1952	635,530	1,839,226	317,531	1,335,480
1953	572,261	1,795,542	249,264	1,046,455
1954	750,090	1,944,938	464,172	1,259,735
1955-56	719,357	1,913,217	452,915	1,280,223
1956-57	706,310	1,959,954	443,716	1,359,486
1957-58	475,722	1,932,000	412,033	1,368,000
1958-59	975,336	2,109,000	497,544	1,320,000
1959-60	1,070,519	3,125,000	662,105	1,796,000
1960-61	1,160,576	4,175,000	722,031	2,226,000
1961-62	1,187,397	4,987,000	736,970	2,816,000
1962-64	1,291,825	—	795,120	—

During the last ten years (1953-54 to 1961-62), the IISCO produced steel valued at Rs. 6,600 millions, the value of which if imported from U. K. would have been Rs. 9,260 millions thus saving a net amount of Rs. 2,660 millions in valuable foreign exchange, which, in fact, is the cost of a new one million tonne capacity integrated steel plant. The retention price for IISCO steel in April, 1963 is :—Bloom-365, Billet—398, Slab—383, Hoe Bar—464, Heavy Rail—512, Lt. Rail—574, Hy. Bar—486, Lt. Bar—505, Steel—525, Bl. Sheet—668, and glvd. Sheet—782.

The estimated total annual requirement of raw material and electric power for the IISCO plants is as follows :—

Coal	2.506	million	tonnes
Iron-Ore	2.215	,,	,,
Manganese-Ore	0.04	,,	,,
Limestone	0.66	,,	,,
Dolomite	0.04	,,	,,
Electric power	36,000 kw.		

The IISCO obtains iron-ores from Gua, Monoharpur, Ajita, Maelean mines in Singhbhum, Bihar ; and coal from their Chasnala, Jitpur, and Ramnagar Collieries in Jharia and Raniganj coalfields. It has to handle about 5,775 tonnes of iron-ore per day at present. The colliery expansion scheme of the Company will provide at least 85 per cent. of their coking coal requirement with a consistent grade of coking coal approx. 17.5 per cent. ash by crushing, washing and by blending. The target is 4,200 tonnes of washed coal per working day. The Company, after all its expansion programme is implemented, expects to produce two million tonnes of ingot equivalent and 1. 6 million tonnes of finished steel (*The Statesman*, dated 14. 11. 62).

The Steel Corporation of Bengal (SCOB) floated in 1937 under the managing agency of Messrs. Burn & Co., merged with IISCO since 1st January, 1953. The SCOB had two 25. 4 tonnes acid converters and three 228. 6 tonnes basic open hearth tilting furnaces and one 91. 4 tonnes fixed furnace, having an annual production capacity of 355,616 tonnes of finished steel.

The Kulti foundries of IISCO achieved a record production of 230,423 tonnes during 1961.

Durgapur Steel Works :— It is a recent enterprise in the Public Sector under the management of the Hindustan Steel Ltd.

The factory is located at Durgapur (23°29′:87°18′), in the Burdwan district, on the Calcutta-Delhi main line of the Eastern Railway, and is about 161 km. west of Calcutta.

The Steel Plant has the following component parts :—

1. Three blast furnaces each with a daily production capacity of 1,250 tonnes of pig iron.

2. Three batteries of coke ovens containing 78 ovens each.

3. Eight open hearth furnaces, out of which seven with a capacity of 200 tonnes of steel per day and one with a capacity of 100 tonnes of special steel for the wheel and axle plant of the Works.

4. Two mixers for steel melting.

5. Three rolling mills including one blooming mill (1. 1 m.), one continuous billet mill and one wheel, tyre and axle plant.

6. One power plant of 150,000 kw. capacity, and

7. One coal washery plant of 350 tonnes per hour capacity.

The first coke oven battery was lit on the 24th August, 1959 while the second coke oven was lit on the 1st October, 1962 and commenced production during December 1962, and the Steel Plant was commissioned on the 29th December, 1959. The production of steel started from the 25th April, 1960 when the first open hearth furnace was commissioned. The first consignment of finished steel in the form of billets left the Steel Works on the 27th June, 1960. The first blast furnace produced 8,720 tonnes of pig iron during the week ending 12th November, 1960, and produced 1,413 tonnes of it on the 27th September, 1960, exceeding the rated daily capacity of 1,270 tonnes. The production of steel ingots from the Durgapur plant during 1963 was 970,000 tonnes. The Durgapur Steel Works, with the completion of all its component parts, has been designed to produce 1,016,000 tonnes of ingot steel, and 812,800 tonnes of saleable steel and 366,000 tonnes of pig iron for sale. The plant has a provision for expansion up to 2,540,000 tonnes of ingot steel per year.

The coke oven plant when fully commissioned will produce chemical by-products like benzene (three million litres per year) toluene (4,000 litres per day), xylene (450 litres per day), solvent naptha (660 litres per day), tar (700 litres per day) and coal gas of 1. 7 million cu. m. per day.

The estimated total annual requirement of raw materials and power at present for the Steel Plant will be, coal-1.87 million tonnes, iron-ore-1.98 million tonnes, manganese-ore-0.065 million tonnes, limestone-0.629 million tonnes, dolomite-0.428 million tonnes and electric power-40,000 kw. The iron-ore requirements of the plant will be met from the newly opened mine at Bolani in Orissa, and of coal by blending the Jharia coals with the high volatile semi-caking coals of Barakar, limestone from the existing sources in Birmitrapur and Bari in Bihar, and water from the Damodar river. Jharia coal will be washed in the washery set up as a part of the main steel plant.

Apart from these main producers of iron and steel in the State, there are secondary producers, called Billet Re-Rollers, like the one run by M/S Guest Keen Williams, Calcutta, and Scrap Re-Rollers, also called "Unregistered Re-Rollers". Recently, the Government of India has granted licence to the Todi Steel Corporation, Calcutta to set up a small pig iron plant of 15,241 tonnes annual capacity at calcutta.

The following products will be manufactured:—

(i) Billets for re-rolling (152,000 tonnes.), (ii) Sleeper bars (61 thousand tonnes), (iii) Heavy forging blooms(10.2 thousand tonnes), (iv) Forging blooms (30.5 thousand tonnes), (v) Forging billets (61 thousand tonnes), (vi) Marchant bar sections (244,000 tonnes), (vii) Light and medium sections (203,000 tonnes), (viii) Wheels, tyres and axles (50.8 thousand tonnes) and (ix) Pig iron(356,000 tonnes).

Investments & Prospects

The State of West Bengal contributed over 24 per cent. of the India's total output of pig iron and also 21 per cent. of finished steel production through her steel plants in 1961.

By the end of the Fourth Plan i.e. 1970-71, pig iron production is likely to be of the order of 2.15 million tonnes while that of steel of the order of 17.3 million tonnes, in the country. By that period i.e. 1961-71, the steel output of the State of West Bengal is anticipated to increase to 4.06 million tonnes with planned expansion of her existing steel units through an investment of about Rs. 2,000 millions for the additional output of 1.52 million tonnes.

The State leads in various ancillary engineering industries. It is estimated that in 1956, 25 per cent. of India's engineering establishment (utilizing 33.3 per cent. of the production capital) were located in the State which accounted for 40 per cent. of the net value of the country's production of engineering goods. Already, such large engineering establishments as (i) the Locomotives factory at Chittaranjan (ii) the cable factory at Rupnarayanpur (iii) Mining Equipment factory at Durgapur (iv) Scientific Industrial factory at Calcutta (v) Vehicle factory of Hindustan Motors Ltd. at Uttarpara (vi) Bicycle manufacturing industry near Asansol are located within the State.

All or most of these factories utilize steel material in one form or another. Since iron and steel are the base of industrial development, with the expansion of the iron and steel industries through large and small scale plants, the much needed industrial growth of the State as well as of the country will have sound foundation and will also lead to fuller growth of ancillary engineering industries for the State.

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CHAPTER XIV

Calcareous Materials/Minerals

LIMESTONE

General

One of the most useful raw materials for the industrial development of a country is limestone. It consists mainly of calcium and magnesium carbonate. Limestone, containing over 20 per cent. magnesia is known as dolomite. The specific gravity varies from 2.72 to 2.83, and hardness from 3 to 4 in the Moh's scale.

USES : Limestone has many uses. The principal utilization of limestone is in the manufacture of Portland cement which is closely followed by its use as flux in Iron and Steel industries. It is also used in chemical industries for the manufacture of calcium carbide, bleaching powder, in sugar refining and in tanning industries, in papers, glass and ceramic, and textile industries, agriculture water purification, rock-wool industries, etc. Thus an increase in the production of limestone is related to the growth of Cement and of Iron and Steel industries in particular.

Specifications

1. *Flux* : Limestone used as flux in the manufacture of iron and Steel should be dense, massive, preferably fine-grained and compact, non-fritting on burning and it should be able to withstand crushing under load in the furnace. Slightly crystalline varieties may also be suitable provided the crystals of calcite are small and the material is not liable to easy crushing. $CaCO_3$ should not be less than 90 per cent. SiO_2 and Al_2O_3 not more than six per cent. silica should be within five per cent. magnesia within four per cent. and sulphur and phosporus should be as low as possible. The material should be in the form of blocks of 5 to 10 cm. in size.

2. *Furnace lining* : Limestone used in furnace lining should be of crystalline variety with silica less than five per cent. magnesia about two per cent. insolubles within one per cent. and $CaCO_3$ at 85 per cent. Blocks of the sizes of 10 to 15 cm. are preferred.

3. *Cement* : Specification of ordinary and rapid hardening Portland Cement (given by I. S. I.) (Limestone which satisfies the above specification may be used for Portland Cement).

(a) Ratio of percentage of lime after deduction of the amount necessary to combine with sulphuric anhydride present, to percentages of silica, alumina and iron oxide when calculated by the formula:—	= Not greater than 1.02, not less than 0.66.

$$\frac{CaO}{2.8 \times \%\ SiO_2 + 1.2 \times \%\ Al_2O_3 + 0.65 \times \%\ Fe_2O_3}$$

(b) Ratio of percentage of alumina to that of iron oxide	= Not less than 0.66
(c) Weight of insoluble residue	= Not more than 1.5%
(d) Weight of magnesia	= Not more than 5%
(e) Total sulphur content calculated as sulphuric anhydride (SO_3)	= Not more than 2.75%
(f) Total loss on ignition	= Not more than 4%

4. *Chemical requirements.*

(a). *Calcium Curbide* : Specifications are available only for quicklime. According to A. S. T. M. standard specification C 258-52, quicklime should be substantially free from ash, core and dust, and it should be in pebble or lump form. The chemical composition is shown below.

	Per cent.
Total lime, CaO (min.)	92.00
Magnesia, MgO (Max.)	1.75
Silica, SiO_2 (max.)	2.00
Insolubles, $Fe_2O_3+Al_2O_3$ (max.)	1.00
Sulphur, S (max.)	0.20
Phosphorus, P (max.)	0.02
Loss on ignition on sample taken at place of manufacture	4.00

(b) *Soda ash* : Specification for alkali industry Soda ash by *Solvay soda process* :

$CaCO_3$	90 - 99
$SiO_2 + Al_2O_3 + Fe_2O_3$	0 - 3
$MgCO_3$	0 - 6

(c) Bleaching powder : Specification of quicklime in bleaching powder (on non-volatile basis)

CaO (min.)	95
$Fe_2O_3 + Al_2O_3 + Mn_2O_3$ (max.)	2.0
(Fe_2O_3 - not more than 0.3%)	
MgO (max.) 2.0% and SiO_2 (max.)	1.5

(d) *Sugar manufacture :* Limestone for use in sugar manufacture :

	Per cent.
CaO (min.)	50
MgO (max.)	1.0
$Fe_2O_3+Al_2O_3$ (max.)	1.5
Silica and insoluble (max.)	4.0
Available lime (min)	80

5. *Building stone* : Composition of limestone is immaterial. Appearance, cost of working and price are the only considerations.

6. *Plaster and mortar* : Limestone of ordinary quality is required. Presence of clay is often an advantage. Very often *kankar* which occurs as a surface deposit is collected and burnt.

7. *Chemical industry* : A very pure limestone is required. A low percentage of quartz is permissible. Iron should be below 0.20 per cent. and combined impurities less than from one to two per cent.

8. *Flux in glass* : Pure limestone is essential. Some amount of free quartz and alkalies are permissible, but magnesia and iron are undesirable, and alumina should be low.

9. *Mineral wool* : For heat and sound insulation, limestone of any quality is permissible together with silica.

10. *Agriculture* : Lime is added to the soil to correct soil acidity and improve tilth. It acts as a soil conditioner. The limestone required may be of any quality.

11. *Paper* : Lime is used as a constituent of acid liquor. It should be low in magnesia. In the manufacture of straw board the lime may be high in calcium and magnesium.

12. *Water purification* ; Lime is added to water to remove hardness. It is also used as a coagulating agent and is germicidal to a certain extent. For this purpose quick lime or hydrated lime are required. The former should contain at least 85 per cent. CaO and the latter 90 per cent. of available Ca $(OH)_2$.

13. *Tanning* : Lime is used at the depilatory stage of leather processing. High calcium lime is generally used.

Consumption

The total consumption of limestone during 1960 was estimated at 13 million tonnes as compared to 10 million tonnes in the

preceding year. The industry-wise consumption of limestone from 1959 to 1962 is given in Table 15 below :

TABLE 15.—*Industry-wise consumption of limestone, 1959—1962.*

(in '000 tonnes)

Consuming industry	1959	1960	1961	1962
Cement	8,120	10,230	11.520	10,959
Iron, Steel & Ferro-manganese	1,560	2,030	2,620	2,876
Paper	252	287	144	155
Chemical (Calcium carbide, Caustic Soda, Soda ash, bleaching powder)	193	213	430	328
Sugar	150	170	163	203
Glass	64	65	54	21
Fertiliser	—	—	268	103
TOAL	10,339	12,995	15,199	14,645

Industry and Prospects :

Cement. The cement industry for which, limestone is the chief raw material, has witnessed a phenomenal growth due to the raw materials being available in plenty in the country, but still has not been able to achieve the Second Plan (1956-1961) target of production of about 11-12 million tonnes, one of the reasons being the restrictions imposed on the import of machinery due to foreign exchange difficulties.

The Associated Cement Companies Ltd. are producing some of the machinery within the country. The Heavy Engineering units in Durgapur, erected by the Associated Cement Co. in conjunction with M/S Babcock and Willcox Co, and Vickers of the U. K. and other engineering establishments are also engaged in the fabrication of cement manufacturing machinery. For erecting a plant with an average capacity of 1.27 million tonnes every year, it will be necessary to invest in machines worth about Rs. 80 millions.

Sufficient progress has been achieved in spite of the difficulties outlined before. During the year under review, 32 units reported production and among them one is a new unit that went into production during 1960. A new company, Mysore Cements Limited, has also been floated. Nine new factories are expected to be erected shortly by the existing producers.

Cement is commonly manufactured by the wet process, but it has recently been felt that the dry process is more economical as the water and fuel requirements are reduced. The Mysore Cements Limited would be manufacturing cement by the dry method at Ammasandra in Tumkur district, Mysore State. Cement is also produced using limeshell, blast furnace slag, or *kankar* instead of limestone. The plant at Sindri utilizes the sludge obtained as a by-product in the manufacture of ammonium sulphate.

Fertilizers : Limestone is one of the chief raw materials required for the manufacture of nitro-lime fertilizers. The Government of India have set up two plants in the public sector to manufacture nitro-lime, one at Nangal in Punjab and the other at Rourkela in Orissa. The annual production targets are 345,000 and 71,000 tonnes respectively. Both plants have commenced production.

Iron and Steel and other allied industries : The iron and steel industry consumes limestone in appreciable quantities in two grades, one for fluxing in the blast furnace and the other for felting in the steel melting shops. The envisaged increase in target capacities for iron and steel by the end of Third Five Year (1966) Plan also calls for a larger consumption of flux grade material.

The Bhilai Steel Plant obtains its limestone requirements from the highly machanised Nandini mines in the Madhya Pradesh. Limestone for the Rourkela Steel Plant is obtained from Purnapani in Orissa and from Satna-Maihar in Madhya Pradesh. The Durgapur Steel Plant obtains the flux from Birmitrapur in Orissa. The Mysore Iron and Steel Works obtain limestone from their own quarries at Bhandigudda in the Shimoga district, Mysore.

An annual target of production of 30 million tonnes of limestone is envisaged during Third Five Year Plan to meet the requirements of cement, flux and other chemical industries.

In West Bengal, there are four possible sources of raw materials for lime manufacture, *viz.* (1) Limestone- (a) crystalline limestone found in the Archaeans in the Purulia, Bankura, Darjeeling and Jalpaiguri districts (b) Limestone associated with the Gondwanas in the Panchet area in the Purulia district, and with the Gondwanas and Siwalik formations at the foothills of Darjeeling and Jalpaiguri districts. (2) Dolomites-extensive dolomite deposits have been found in the Jalpaiguri district, and a few minor bands in the

crystalline Archaean tracts of Purulia and Bankura districts (3) Calcareous tufa in Darjeeling district, and (4) Calcium carbonate concretions (*ghootings* and *ghusiks*) found extensively in some places of Purulia, Burdwan, Bankura, Midnapur and Birbhum districts.

Although India is well endowed with this important raw material, the distribution of cement and flux grade limestone in West Bengal is not so encouraging. The State has vast deposits of dolomite which is getting increasing use in the Iron and Steel industries, and a good deposit of impure siliceous limestone which may in future be utilised after proper blending and beneficiation for cement manufacture. The Panchet limestone was once used as a flux by Barakar iron smelters in earlier days. The Limestone of Purulia and Bankura, the dolomite of Jalpaiguri, and the *kankars* are used for lime burning since a long time. The production of limestone in West Bengal in 1952 was only 4,608 tonnes, it rose to 11,488 tonnes in 1955, and to 26,584 tonnes in 1957. The requirement of flux-grade limestone in 1961 for the Indian Iron & Steel Co. and the Durgapur Steel Project was 711,235 tonnes and 609,630 tonnes respectively, totalling a requirement of 1,320,865 tonnes in the State. The requirement of this raw material by the end of the Third Five Year Plan in 1966 will be a total of 2,540,325 tonnes, with about 1,320,865 tonnes for IISCO and about 1,219,260 tonnes for the Durgapur plant. The requirement of dolomite for furnace lining in IISCO and Durgapur was 50,303 tonnes for each of them in 1961, and the probable requirement by the end of the Third Five Year Plan in 1966 will be 101,600 tonnes for each of them.

Distribution

Bankura District

(1) *Harirampur* (23°08′ : 86°45′) ; Eight small and detached exposures of crystalline dolomitic limestone are found in the neighbourhood of Harirampur village. The maximum area of one of these outcrops is 198 m. by 20 m. which occurs to the south-east of the village.

The limestone bands show fairly steep dip towards the south-east, having strike directions varying between N.N.W.-S.S.E. to N.W.-S.E. Indications of faulting amongst them, marked by the presence of silicified rocks (sometimes brecciated) and colloidal silica (like agate), are

noticed. The country rock is quartz-mica schist with bands of hornblende-schist and quartzites. Few pegmatites are also seen.

Assuming that each of the apparently detached outcrops around Harirampur village extends down to at least 15 m. Hunday (1951) estimated an approximate reserve of 1.88 million tonnes of this dolomitic limestone in the area. He distinguishes four main types which have the following average bulk composition :—

	SiO_2 %	Fe_2O_3 + Al_2O_3 %	CaO %	MgO %	loss on ignition %	Total %
Type 1 (Yellowish grey, medium-grained with white specks)	13.62	2.10	36.49	11.13	36.58	99.92
Type 2 (Bluish grey, medium to coarse-grained with white specks)-	10.32	2.40	33.74	16.78	36.32	99.66
Type 3 (Medium-grained grey limestone)	10.18	2.20	34.23	15.16	38.44	100.21
Type 4 (white coarse-grained marble like)	2.06	2.00	30.85	20.34	44.86	100.11

Some of these limestones after polishing may be used as ornamental building stones. Locally, these limestones are burnt for the manufacture of lime. These are not suitable for cement industry.

(2) *Guniada hillock* (.208 m. 23°09′ : 86°45′) : A small exposure 30.5 m. by 409 m. of crystalline limestone is found about 91 m. S.S.W. of Guniada hillock near Harirampur village.

P. K. Chatterjee (Krishnan, 1958) examined several patches of these crystalline limestone lying S.S.E. and E.S,E. of the Harirampur village, and he thinks that about 254,000 tonnes of limestone will be available from this area for every three metres of depth. He is of the opinion that the deposit is not large enough for large scale development, but can be worked locally for lime burning.

(3) *Champabani* (22°50′ ; 86°56′) : Hunday reported the occurrence of a small exposure of impure crystalline limestone near the Mangalgara *Nadi* section about 800 m. west of Champabani village, The exposure is five metres long N N.W.—S.S.E., and is about 7.4 m. wide. The

country rocks are quartz-schist, quartzite, hornblende-schist and kaolinised sericite-schist.

Purulia District

(1) *Jhalda* (23°22′ : 85°59′) *area* : These are the most important occurrences of limestone within the district as well as in whole of West Bengal. In recent times lot of work has been done on these limestone deposits by the Geological Survey of India, the Jhalda Raj Estate, and the Government of West Bengal. The State Government is very keen to explore these deposits for setting up a cement factory, as at present there is no cement factory in the State.

The Geological Survey of India had investigated these deposits in some detail in 1949-50, and estimated a reserve of about 1.016 million tonnes to a depth of about 15.24 m. in the Jabar (23°27′ : 86°01′) area. The detailed investigations of these deposits were again undertaken by the G.S.I. at the instance of the State Government during 1957-58.

T. M. Mahadevan (Roy, 1962) investigated the discontinuous patches of crystalline limestone occurring :

(1) Along the northern slope of the Jabarban hill (23°27′ : 86°01′) north of Jabar village which is about 15 km. north of Jhalda by road.

(2) Along the southern slope of the hill north of *Ichatu* (23°28 : 85°53) and Digardih (23°28′ : 85°52′), about 16 km. north-west of Jhalda by road.

(3) Thin and small lenses of limestone along the southern slope of the *Belamu* hill (23°28′ : 86°03′), about 3.22 km. E.N.E. of Jabar.

The Jabar deposit is served by a jeepable road from the 25th mile-stone on the Purulia-Jhalda road. The Begunkudar and Jhalda Railway Station on the Purulia-Ranchi metre gauge section of the South Eastern Railway lie about 10 to 14.5 km. south of the Jabar deposit, and the new railway line connecting Phusro, and Muru is 3.2 to 8 km. away from the Jabar deposit and five kilometres from the Ichatu deposit.

The limestone bands occur in a discontinuous zone of calcareous meta-sediments (calc-granulites, calcareous quartzite, amphibolites and marbles), bounded on the north by porphyritic and augen gneisses, and on the south by graphitic sillimanite-mica schist. General strike of the country rocks is E.N.E.-W.S.W. to E.S.E-W.N.W. dipping 60° to 85° north or south, but more commonly

to the north. The limestone bands are lenticular, tightly folded and might be repeated.

In the Jabar area, the largest limestone band having a width varying from 45.7 to 91.4 m. could be traced for about 1.6 km. Numerous pegmatite veins are present in the band. Calc-silicate rocks are found on the northern side of the hill. It is at places admixed with quartzites and calc-gneisses. Relatively purer lenses are rather small, in places 1.22 to 1.83 m. wide and 9.1-12.2 m. long, otherwise the fine-grained limestone contain flakes of biotite and lenses of biotite-quartz schist. The limestone is crystalline medium to fine-grained, siliceous in places and contain much free quartz. They grade into calcareous quartzite at places.

The chemical analysis of groove samples collected from these Jabar limestone bodies by C. K. R. Sastry (Krishnan, 1953) show silica varying from 36.2 to 54.88 per cent. magnesia 2.18 to 2.89. per cent. and the purer portions show silica 7.99 to 29. 28 per cent. magnesia traces (0.25 to 0.95 per cent.), and lime 39.01 to 50.08 per cent. T. M. Mahadevan (Roy, 1962) found insolubles 22.43 to 34.46 per cent. magnesia 0.34 to 0.47 per cent. lime 36.27 to 50.86 per cent. and Al_2O_3 plus Fe_2O_3 0.25 to 0.95 per cent. In a majority of these limestones, the insoluble percentage varies between 20 and 35. Mahadevan calculated a reserve of 2.74 million tonnes of limestone in the Jabar area, assuming a length of 1,220 m., workable width of 30.5 m. and depth of 30.5 m. Limestone having 7 to 25 per cent. insolubles will be only about 10 per cent. of the total reserve. In 1958 G. N. Dutt and T. K. Guha Sarker (Roy, 1962) calculated about two million tonnes of limestone reserve in the Jabar area. The reserve at Maramu near Jabar is reported to be about 44 million tonnes with 25.91 per cent. insolubles.

The marbles in the Ichatu (Digardih) area occur in six isolated patches intercalated with the Archean quartzite and calc-gneiss. Quartz and calc-silicate minerals (wollastonite, epidote, pyroxene etc.) are the main impurities in the marbles. The percentages of magnesia, alumina and iron-ore are low. The average silica content is about 34 per cent. The purer band, about 0.61 m. wide and 6.1 m. long, shows 9.4 per cent. insolubles; and the impure band, about 2.44 m. and 6.1 m. wide long, shows 21.28 per cent. insolubles. G. N. Dutt (Roy,1962a) has calculated a reserve of

roughly one million tonnes in this area and remarked that this limestone is unsuitable for the manufacture of Portland cement. T. M. Mahadevan (Roy, 1962) remarked that the purer portion of these limestone bands may be used for manufacturing lime.

The Jhalda limestones may be subjected to beneficiation processes to make them free from impurities (quartz, biotite, wollastonite etc.) as in the Khalari Cement Works of M/S Associated Cement Co. insolubles are reduced from 24.4 to 8.4 per cent. by froth floation. This possibility should be examined, and the limestones may be further blended with better quality limestone available nearby.

(2) *Hansapathar* (23°38′ : 86°40′) : White crystalline limestones, fine to coarse-grained including strings and nests of quartz and felsper and disseminated crystals of actinolite, occurring 800 m. west of Hansapathar to the south of Raniganj coalfield, have been quarried in the past. The limestone bands have been traced upto 3.2 km. along the strike and are reported to be about 21.3 to 30.5m. thick. But only 1 to 1.22 m. of this thickness is of good quality. One limestone band of 7.6 m. thickness occurs to the north of the Hansapathar village, and another of 45.7 m. thickness occurs north of the Asta village. The availabe reserve of this impure and siliceous limestone is reported to be 1,270,000 tonnes. Khedkar and Ramaswamy (West, 1950) gave the chemical analysis of four representative samples, in which CaO percentage varies between 27.95 and 31.91 MgO between 0.81 and 1.70, loss on ignition from 24.64 to 26.71, insolubles (including SiO_2) between 37.23 and 42.38 and Fe_2O_3 and Al_2O_3 from 1.25 to 3.40.

The search for limestone in the area west of Hansapathar did not reveal any occurrences (West, 1950, p. 139). The chemical composition of this limestone is given below :—

	Per cent.	*Per cent.*
$CaCO_3$	83.43	67.30
$MgCO_3$	0.78	0.57
$FeCO_3$	0.68	0.73
P_2O_5	0.02	—
Al_2O_3	—	0.09
Insol.	16.18	31.31
Total	101.09	100.00

Besides these limestones, there are a few small occurrences of crystalline limestones within the Iron-Ore series in the Purulia district. They are at (3) *Kultanr* (22°59′ : 86°34′) : (4) *Tamakhun* (22°59′ : 86°36′) ; (5) north-west of *Kumari* (22°58′ : 86°38′) ; (6) *Gobindapur* (22°58′ : 86°39′) (7) *Mirgichanda* (22°58′ : 86°41′) ; and (8) south-west of *Kantagora* (22°58′ : 86°39′). They are usually small, the largest being at Tamakhun and north-west of Kumari, the former is 1.83 m. in length and 12.2-15.2 m. in width at the outcrop.

Bedded limestones occurring within the Lower Panchets of the Gondwanas are found near *Baghmara* (23°39′ : 86°45′), north-west of Panchet hill, to the south of the Raniganj coalfield. The limestones are dark grey in colour and massive in appearance. The deposit can be traced for a length of 152 m. and has an average thickness of 6.1 m. (Roy, 1938). The beds dip from 15° to 30° towards the south-east. Roy (1938) calculated the available reserve of this limestone deposit as 2.5 million tonnes assuming a strike length of 183 m., length along dip 91.4 m., and a thickness of 6.1 m. Mallet (1877) observed two bands of limestone ; one massive, bedded and dark grey, 3 to 3.6 m. in thickness, and the other to the south which is arenaceous and 5.5 m. in thickness. A few other deposits of impure limestone of concretionary nature are also found in the immediate vicinity. The chemical composition of the limestone is given in the following three analyses, No. 1 quoting from Roy (1938), and Nos. 2 and 3 from Mallet (1877).

	1 *Per cent.*	2 *Per cent.*	3 *Per cent*
$CaCO_3$	65.03	63.40	45.05
$MgCO_3$	3.78	14.41	11.53
$FeCO_3$	—	4.15	3.64
Al_2O_3	5.28	—	—
Fe_2O_3	5.17	0.62	0.28
P_2O_5	n.d.	0.12	0.07
Insolubles	20.86	19.28	39.28
	100.12	101.98	99.85

(n. d.—Not determined)

This limestone was once used as flux in the Barakar Iron Works at Kulti in the earlier days, and may be utilised now for making lime.

Gee (1932, p. 304) cited an outcrop of limestone of unknown extent at Jamuan, (9.6 km.) south of Raniganj, together with a dolomitic limestone near Ramlallpur, 11 km. south of Raniganj.

Darjeeling District

A few scattered occurrences of coarse crystalline limestone bands, ranging in thickness from 1 to 1.22 m. and interbedded with numerous quartzites and sandstones, have been reported by Stefanski (1948) from the Kalimpong sub-division of the Darjeeling district. These are located (1) in the *Palla* (27°03′ : 88°34′) *Kankibhong* (27° 05′ : 88°40′) *khasmahals* in the Lawa forest ; (2) in the *Rhenok stream*, the tributary of Rishi *Chu* ; (3) in the *Bindi stream*, a small tributary of Rishi *Chu* ; and (4) in the *second big stream* on the road from Maria to Nishinchun.

Regarding the first occurrence, Stefanski thinks that they have been formed by leaching out of the underlying ultrabasic rocks (peridotites and pyroxenites), while the second occurrence is reported to lie between ultrabasic rocks, quartzites and ortho-gneisses on the one side and quartz biotite gneiss and graphitic schists on the other. Stefanski reports that about two million tonnes of good limestones will be available from the Palla-Kankibhong *khasmahals*, and that these limestones (Cuddapah age) never occur above an elevation of 914 m. Further extension of this limestone south-east ward in a stream for about 1.2 km. has also been noted by Stefanski which according to him may yield about one million tonnes. The No. (2) and (3) occurrences will hardly yield one million tonne of limestone according to the same author.

The Isolated occurrences of these limestone near Palla, Kankibhong Lawa, Bindi Lingsekha (27°08′:88°41′), and Maria (27°07′ : 88°39′) are scattered over a large area. The total quantity available from these occurrences, according to stefanski's estimate, may range from a few hundred thousand tonnes to two million tonnes at the most. In quality, the limestones are recommended for various industrial uses *viz.* cement manufacture, lime burning, ornamental and building stone but the scattered nature of the occurrences and the lack of road facilities will put some difficulties for the commercial exploitation of these limestones.

(5) In addition to the above occurrences, limestone bands overlying the coal-bearing formations, and limestone boulders with

Tertiary fossils, (*Planorbis* etc.) in the small tributary *nalas* of the Lish river in the Darjeeling district were noted by Hunday (krishnan, 1958, p. 45) of the Geological Survey of India. Besides these, segregations of $CaCO_3$ nodules grading into a sort of irregular beds of impure grey or yellowish limestones are also reported from the Darjeeling and Jalpaiguri districts. Detailed investigation will, however, be necessary to ascertain the reserves and quality of most of these occurrences.

Considerable deposits of calcareous tufa are found in the Darjeeling district and western Duars area of the Jalpaiguri district. The tufa deposits generally contain more than 45 per cent. of $CaCO_3$, and are derived from the dolomite of the Buxa series, impure limestones of the Tertiaries, and calcareous bands of the Daling rocks. The tufa deposits are reported to be commonly found along the Tertiary-Gondwana boundary, probably on account of the existence of springs at these places. Such small deposits of calcareous tufa are found (6) south of *Latpanchar* (26°54′ : 88°24′), and (7) in the *Gola* river and (8) in the *Andhera* blocks of Sukna-Tista reserved forest.

S. Krishnaswamy (1959, p. 104) thinks that some of the calcareous tufa of Darjeeling district may be found suitable for the manufacture of calcium carbide, after proper testing.

JALPAIGURI DISTRICT

Thin, discontinuous bands of crystalline limestones which are very restricted in distribution, occur within the Siwalik sandstones and shales.

(1) Thin and impersistent beds of bracciated limestone associated with bands of hematite-quartzites are reported to occur at the junction of the Dima river and its tributary about 800 m. south-west of Adma (26°46′ : 89°33′) near peak 1,266 ref. height in the Jalpaiguri district. The limestones are veined by quartz stringers, and contain muscovite, chlorite and limonitised pyrites (west, 1950, p. 149).

(2) Similar limestone beds are found along the *Raimatong nala* (west, 1950, p. 149).

These limestones are not of much economic importance except as a source for lime and for building materials.

The production of limestone in West Bengal from 1956 to 1962 is given below :—

Year	*Quantity (in tonnes)*	*Value (Rs.)*	*Total Indian production (in tonnes)*	*Value (Rs.)*
1956	9,118	16,000	8,385,385	
1957	26,584	81,000	9,571,058	
1958	6,304 (Jalpaiguri)	20,000	10,533,497	41,531,000
1959	4,881 (Jalpaiguri : 2,442; Purulia : 2,439)	26,000 (6,000 ; 20,000)	10,831,496	45,723,000
1960	2,811 (Jalpaiguri : 45; Purulia : 2,766)	21,000		
1961	7,988	51,000		
1962	29,109	1,96,000		

The National Council of Applied Economic Research in their Techno-Economic Survey of West Bengal suggested that the State should aim to increase its limestone production to the tune of 101,600 tonnes annually by 1970-71 and in this connection an investment of Rs. 700,000 has been suggested for mining and development of the limestone deposits of the State.

Dolomite

Dolomite is a double carbonate of calcium and magnesium, $CaMg(CO_3)_2$, and often occurs as marble. The hardness varies from 3.5 to 4 in moh's scale, and sp. gr. from 2.8 to 2.9. It is generally white and grey in colour, but may have at times a yellow or brown tinge. Rarely it is red, green or black. Commercial dolomite may contain magnesium carbonate varying from 10 to 40 per cent.

Dolomite is mainly used in industry as a calcined product for refractory purposes, as a basic lining in open-hearth furnaces and Bessemer Converters, for which a dead burnt product is used. This is also used in the manufacture of high magnesia lime, basic magnesium carbonate, (with asbestos in making 85 per cent. magnesia heat insulating matter) epsom salts, and metallic magnesium, in the chemical industry, in the manufacture of paper, leather, glass etc., and as a fertiliser on acid soils. This can also be used as a building stone as terrazzo, stucco dash, concrete block facings or as crushed stone.

Dolomite for use as a refractory furnace lining in steel making should contain over 35 per cent. $MgCO_3$, with silica less than one per

cent. and iron oxide and alumina not exceeding 1.5 per cent. the remainder being $CaCO_3$. For use in refractories, dead-burnt dolomite is commonly used. It is made by calcining dolomite to about 1,500°C either in blast furnace or in a spcial kiln. The material suitable for furnace lining should be fine-grained, preferably cryptocrystalline and compact. When used as a flux in blast furnace, dolomite should contain CaO 29.0% ; MgO 20.0% ; SiO_2 4.0%, and Al_2O_3 2.2%. In the ferro-silicon reduction process during the manufacture of magnesium metal, the calcined dolomite used as a raw material is stated to contain MgO 40.5% ; CaO 58.1% ;$Fe_2O_3+Al_2O_3$0.8% and insoluble matter 0.5%. Dolomite for lime manufacture contain $CaCO_3$ 54 to 72% ; $MgCO_3$ 28 to 46% and other constitutents 3%. The consumption of dolomite in iron and steel, ferro-manganese and glass indastries was estimated at 435,000 tonnes, 14,000 tonnes and 6,000 tonnes respectively during 1960. Dolomite refractories are manufactured in India by Tata Iron and Steel Co. Ltd., Burn & Co., Ltd., and Orissa Cement Limited. It is claimed that the consumption of dolomite by the L. D. process is only 4.9 kg. for a tonne of ingot steel as against 9.8 kg. by the open-hearth furnace.

Deposits of dolomite are widespread both in relation to geological associations, in various rocks of Pre-Cambrian to Tertiary age and also in geographical distribution in India. The State of West Bengal contain some of the best and extensive dolomite deposits (in Jalpaiguri district) in India.

Recently, magnesium metal was successfully extracted from dolomite by the National Metallurgical Laboratory, Jamshedpur, through the silico-thermal reduction process on a laboratory scale. Testing on Pilot Plants is being carried out for meeting the requirements of ordnance factories. The higher consumption of dolomite in the growing iron and steel industries has been instrumental in bringing out large outputs in recent years.

JALPAIGURI DISTRICT

Extensive deposits of dolomite covering an area of about 13 sq. km. within latitudes 26°42′ and 26°44′, and longitudes 89°32′ and 89°42′ occur in the Buxa Duars area in the north-east corner of the Jalpaiguri district. A reserve of 6.096 million tonnes of high quality dolomite has been estimated in the area. (*The Statesman*, Calcutta, 15. 11. 62). These deposits extend further into the Bhutan territory over an area of about 5.2 sq. km. The nearest railway

station is Jainti, the terminus of the Rajabhatkhawa-Jainti branch line of N. F. Railway. A fair weather road also connects Jainti with Rajabhatkhawa on the Assam-Bengal line of N. F. Railway. The deposits are not easily accessible. The area is covered by a dense vegetation and the terrain is very hilly. The hill ranges rising abruptly from the plains are constituted of rocks belonging to Buxa, Gondwana and Tertiary formations. Rocks are folded and faulted and give rise to precipitous cliffs and steep ravines. The Bengal-Bhutan boundary line passes almost along the crest of the range. The Jainti river is an important river in this area and is fed by a number of *nalas* originating on the hill ranges.

The earliest geological work in the area was done by Godwin Austen (1865, 1868). F. R. Mallet (1875) worked in the western Duars area in the vicinity of the Titi *nadi* about 43 km. west of Buxa. H. H. Hayden visited the area in 1896, and A. Lahiri carried out geological mapping in Buxa Duars in 1937-38. Recently D. K. Chandra (west, 1950) and T. K. Kurien (1959) of the Geological Survey of India have done detailed work on the geology and economic deposits of this area.

The first commercial exploitation of this dolomite was started by the Bengal Lime and Stone Co. in 1932, and later the Jainti Lime Co. started their operations in March, 1947. The above two companies hold mining leases on Majekhola and Duimile *nala* respectively on the north of the main road in part of Sachaphu Reserved Forest. They collect dolomite boulders from these *nalas* and blast them to smaller sizes which are burnt in kilns located at the Jainti railway station. The burnt dolomite is then powdered, packed in gunny bags and despatched for use as whiting and other purposes. A certain amount of slaked lime is also made. The Bengal Lime and Stone Co. have two kilns with a capacity of burning 19 tonnes of material a day. The Bengal Lime and Stone Co. have a proposal to manufacture dolomite bricks at Jainti for use in the new steel factories. In fact, one company of Calcutta has already procured mining leases and started mining dolomite in the adjoining territory of Bhutan for use in the Durgapur Steel Works.

Dolomites are the important members of the Buxa series which are overlain by younger Gondwanas and underlain by the Dalings. The oldest member of the Buxa series is a talc-sericite-schist, overlain by quartzites, quartz-schists, slates, phyllites, hematite-quartz-schists, and

black and grey dolomite with patches and nests of calcite, and calcareous slate with pyrite.

(1) *Sachaphu hill range*: The largest deposit of dolomite in the Jalpaiguri district is located here. It is traceable from Lapchako, east of Buxa (26°45' : 89°36'), to Raidak gorge in the east; afterwards it continues into Bhutan.

There are four bands of dolomite in this area, the northernmost being the most important. This is crescent shaped, bulging out in the central portion which is about three kilometres wide. The length is about eight kilometres from Mahakal (26°44' : 89°39') to Sakhe (26°44' : 89°44') trending roughly W.N.W.—E.S.E. It flanks the southern edge of the Sachaphu and Buxa Reserved Forests, and extends into Bhutan. The eastern part of this deposit is faulted twice.

The other three bands are smaller, and occur to the south of the main band separated by folding and faulting. Their width hardly exceeds a few hundred metres. The largest of them is about 4.8 km. long, extending from east of the Jainti river to the Baje *khola*. The other two are of 1.6 km. length, both trending in W.N.W.—E.S.E. direction. The width of the outcrops towards the west is about 800 m. and the thickness of the dolomite beds is about 610 m., while those towards the east are about 1.6 km. and 914 m. respectively. The best exposures are seen along the Jainti river section, in the vicinity of Bhutan boundary, and along upper reaches of Maje *khola*.

Two varieties of dolomite are seen here, one is light grey, massive with indistinguishable bedding planes, and the other one is a dark brecciated variety with distinguishable bedding planes. Both the types are pure throughout. Light grey variety is more predominant and preferred for lime burning. The dark one occurring at the higher reaches contains layers of argillaceous matter and passes into slate. It contains chert and other siliceous matter, calcite and quartz veins.

F. R. Mallet (1875) gives the following chemical analysis for the two varieties of dolomite found in the Buxa area :—

	Light Grey	White almost crystalline
	Per cent.	*Per cent.*
$CaCO_3$	59.7	60.5
$MgCO_3$	37.8	38.7
Oxides of Iron and Aluminium	1.0	0.3
Insolubles	0.8	—

A. Lahiri gives the following chemical analysis for this dolomite :

		Per cent.
CO_2	....	44.87
CaO	....	38.19
MgO	....	13.65
Fe_2O_3	....	1.28
Insolubles	....	2.15

D. K. Chandra (1947) analysed 16 samples, and the results show the following variations in the chemical constituents :—

		Per cent.
SiO_2	....	0.24 to 7.52 (generally below 1%)
Al_2O_3	....	0.12 to 1.12
Fe_2O_3	....	0.16 to 1.30
MgO	....	19.50 to 21.56
CaO	....	28.20 to 30.30
Loss on ignition	....	42.15 to 47.52

A. K. Dey (1951) gave the average of the above 16 analyses as :

		Per cent.
SiO	....	1.76
$Fe_2 O_3$	....	0.76
$Al_2 O_3$	....	0.48
CaO	....	29.63
MgO	....	21.07
Loss on ignition	....	46.41

T. K. Kurien (1959) analysed 125 groove samples, which show the following variations :—

		Per cent.
R_2O_3	....	0.26 to 3.76 (mostly below 1%)
CaO	....	21.71 to 31.38
MgO	....	13.64 to 23.81
Insolubles	....	0.15 to 26.93 (mostly between 0.15 and 5.57)
Loss on ignition	....	34.46 to 47.30

It will be seen from the above chemical analyses that it has a fairly uniform composition and the majority of the samples approaches dolomite in composition ; thus the chance of obtaining cement grade limestone is rather meagre.

Both Chandra and Kurien think that these dolomites may be suitable for dead burnt dolomite refractory bricks.

(2) *Raimatong* (26°47′ : 89°31′) : A small band of dolomite, about 183 m. long and six m. thick, is exposed along a scarp about three kilometres north of Raimatong, which is about five kilometres north-west of the Buxa railway station. The locality is not easily accessible. The bend is bounded to the east by a cross fault and to the west by a thrust. An analysis of this dolomite by Chandra (West, 1950) is given below :—

		Per cent.
Al_2O_3	....	0.58
Fe_2O_3	....	2.14
CaO	....	28.03
MgO	....	19.66
Loss on ignition	....	43.34
Insolubles	....	6.22
	Total . . .	99.95

(3) *Totapara* (26°50′ :89°19′) : Three small bands of dolomite intercalated with calcareous slate, phyllite and quartzite occur about 2.5 km. north-east of Totapara near the West Bengal-Bhutan boudary. The deposit is about 10 km. north-east of the Lankapara Tea Estate (26°48′ : 89°15′). Two of these bands, each 30 m. thick are located in West Bengal, and the other continues in Bhutan. The northernmost band is the thickest and one sample from this gives the following result (West, 1950) :—

		Per cent.
Al_2O_3	....	0.34
Fe_2O_3	....	1.46
CaO	....	42.84
MgO	....	9.38
Loss on ignition	....	43.78
Insolubles	....	1.52
	Total	99.32

(4) *Lankapara (26°48′ : 89°15′) area and Titi Reserved Forest :*

Besides the above occurrences, dolomite bands have been found further west near the Bengal-Bhutan boundary line north of Lankapara Tea Estate, and in the Titi Reserved Forest area. A dolomite band, about 183 m. thick and 2.4 km.. long within the West Bengal territory, has been located by D. K. Chandra (West, 1950) near the top of a steep ridge forming the Bengal-Bhutan boundary line near boundary pillars (B. P.) 97, 100, 102 and 103. One sample from B. P. 102 gives on analysis :—

Catalogue Materials Minerals

XXXXXX

of argillaceous matter is included; and the proportion of this in some cases is such that, on burning, the *kankar* produces a hydraulic lime or natural cement.

Purulia district : *Kankar* is found scattered in the soil covering granite, basic igneous rocks, etc., of the Archean terrain, and the sedimentary rocks of the coalfield. There are such lime kilns as between Adra (23°30′ : 86°41′) and Rangamati (23°25′ : 86°51′), which utilise *kankar* and local crystalline limestone as raw materials for producing lime.

Bankura district : Reports of fairly numerous occurrences of *kankar* are available from various parts of the district (Hunday, 1949—52, Krishnan 1954,1958). These are particularly abundant in the anorthosite country in the northern portion of the district. These materials are largely used locally for the manufacture of lime. The Burn & Co. lime works at the Mejia village (23°34′ : 87°06′) are mainly dependent on the regular supply of these calcium carbonate concretions. The above lime works have six furnaces, and each furnace measuring 3.7 m. x 2.7 m. x 1.52 m. can consume 22.3 tonnes of *Kankars* which produce about 11 tonnes of lime after working from 10 to 12 days continuously. The coal consumed during the period is about 7.4 tonnes, and the rate of coal consumption is 1.1 tonne per unit production of 3.7 tonnes of lime. According to the local agent, from 1.5 to 1.9 tonnes of lime (CaO) are available out of 3.7 tonnes of *Kankar*. During the four months from January to April 1949, the lime works consumed about 74.3 to 93 tonnes of *Kankar*, and produced 37 tonnes of quicklime.

Kankar is also found to develop over the outcrops of granite and mica-schist in the southern part of the district and in the alluvials plains to the east. In the alluvial country, they occur in comparatively large concentrations mainly on the banks of the Kasai river to the east and south-east of Raipur (22°47′ : 86°57′) and near the Bansi *nadi* further east (Hunday, 1949—53, Krishnan 1954,58).

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Purulia District

Paharpur (22°58′ : 86°15′) : Prospecting for manganese-ore has been done at Paharpur near the Singhbhum border, but the ore is of low grade and not extensive. One analysis gives only 22.2 per cent. of Mn. It occurs within the phyllites of the Iron-Ore series.

Burdwan District

The iron-ores from the ironstone shale of the Raniganj coalfield, contain about 1.4 to 2.5 per cent. of manganese (La Touche, 1918.) But at some places these iron-ores contain somewhat higher percentage of manganese, as near :—

(1) Malchaiti : The iron-ores (Ironstone shale) at this place contain about 16 per cent. of manganese oxide (Piddington, 1829,).

(2) Paolta Kanowa : The same iron-ores from this place show about 10.25 per cent. manganese oxide in them (Piddington, *op. cit.*).

24–Parganas District

Silver Tree G. T. S. Beach (21°58′ : 88°12′) : Numerous small pisolites of manganese-ores occur above the high water landmark on the beach near Silver Tree G. T. S. The origin of the nodules is not known (Fermor, 1909).

There is a steady consumption of manganese-ores in the iron and steel works, in chemical industries and in the manufacture of dry battery cells. Indian manganese-ores and coking coals are generally high in phosphorus in relation to the specification for the manufacture of ferro-manganese. Researches are being carried out at the National Metallurgical Laboratory, Jamshedpur to remove phosphorus from the Indian raw materials. The possibility of establishing a new industry for the electrolytic preparation of metallic manganese, which is used as a deoxidiser in non-ferrous metallurgy, and also for the manufacture of many alloys, may be reviewed in context of the new finds of manganese deposits in the Midnapur district. Other industries, such as the glass and dry battery industries, consuming manganese-ore are also rapidly expanding in the State. In fact, India is now exporting dry cells to neighbhouring countries. In 1956, the IISCO in West Bengal consumed 358 tonnes of manganese-ore for the manufacture of ferro-manganese.

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CHAPTER XVI

MICA

General

Numerous pegmatites containing small books of muscovite are reported from the Archaean tracts of the south-western part of West Bengal, particularly in the Purulia and Bankura districts. Compared to the Bihar mica belt, these sporadic occurrences are of lesser economic importance, but some of these deposits where the maximum size of the mica books has been reported at 169 sq. cm., may have some prospect. A number of mica bearing pegmatites occur in the Bankura district within older schists, e.g., the mica schists, quartz-mica schists etc.,

The muscovite books found in the pegmatites of the Bankura district are usually clear and range from 2.6 to 13.5 sq. cm. in size near the surface. Occasionally large books ranging upto 169 sq. cm. have also been noted within a metre from the surface.

Uses

Mica is the name applied to a group of complex aluminium silicates of potash, iron, magnesia, etc. There are several varieties of mica of which the important ones are white mica, (muscovite.), the amber mica (phlogopite) and the black, or brown mica (biotite).

Mica has a perfect basal cleavage; this enables it to split into very thin sheets and films even upto 1/500th of a centimetre. It is flexible, elastic, transparent and colourless in thin sheets, resilent and tough, chemically very stable, and has a low thermal conductivity and high dielectric strength.

White mica in the form of sheets and splittings is mainly used in the electrical industry. It is used for commutator insulation, armature insulation in dynamos, transformers, electric heaters, rheostats, condensers, radio-tubes, fuse boxes, lamp sockets, sparking plugs and as washers. Considerable quantities of muscovite are used as stove and furnace windows, gas lamp chimneys and shades, furnace peepholes, non-breakable goggles, and for sundry decorative purposes.

Phlogopite is more suitable than muscovite for separating the segments of a commutator and in aeroplane sparking plugs.

Small thin films or splittings of mica cemented together are built up into sheets, and sold as 'micanite'.

Scraps and waste from mines and factories are marketed after grinding them either dry or wet. The dry ground mica is used in roll roofing foundry facings as moulded insulators, automobile tyres, as a filler in rubber goods, in Christmas tree as snow ; and the wet ground product is used in paints, lubricants and wall papers.

Localities

PURULIA DISTRICT

T. M. Mahadevan (Krishnan, 1954) has reported the occurrence of small books of ruby mica, generally about 2.5 sq. cm. or even less but occasionally assuming sizes of even 10.4 cm. across, from the following localities :—

(1) West of *Adabana* (23°09′ : 86°18′).
(2) About 800 m. north of *Bhursa* (23°11′ : 86°26′).
(3) Within 800 m. north-east of *Kumargarh* (23°12′ : 86°23′).
(4) Between *Bhagiari* (23°07′ : 86°26′) and *Ulda* (23°07′ : 86°28′).
(5) 800 m. north of *Ulda*.

These deposits may be worked on a small scale for mica and for a supply of potash felspars.

Books of mascovite, usually varying in length from 2.6 to 5.2 cm. and occasionally 10.4 cm. across, occur in pegmatites at the following localities (Mahadevan, 1954).

(6) 1.2 km. east of *Chuna* (23°24′ : 86°36′)
(7) 600 m. north-west of *Parasibona* (23°25′ : 86°34′)
(8) 800 m. west of *Pinra* (23°24′ : 86°36′)
(9) 800 m. south of *Rudra* (23°25′ : 86°38′).

The mica occurs disseminated throughout the pegmatites. It has also been reported to occur in pegmatites in the following places :—

Kashipur (23°26′ : 86°40′), *Gourangdih* (23°26′ : 86°46′), *Jashpur* (22°48′ : 86°36′), *Ghatbera* (23°11′ : 86°13′), *Marlong* (23°27′ : 86′01′), *Chitra* (23°32′ : 86°26′), *Kanki* (23°35′ : 86°29′), *Taherabera* (23°28′ : 86°02′), *Jabar* (23°27′ : 86°01′), *Maramo* (23°28′ : 86°02′), *Simni* (23°27′ : 86°00′), *Churku* (22°49′ : 86°36′), *Jhairbaid* (22°50′ : 86°36′), Between *Urma* (23°43′ : 86°42′) and *Chirudhi* (23°43′ : 86°37′), *Kadori* (23°22′ : 86°50′)

Mica mining was carried out in the past at Kadori, Chitra Sonkupi Loha, Rangamati and Sirum (23°08′ : 86°02′).

Bankura District

The mica-bearing pegmatites in the district are distributed in the various parts of Chatna, Indpur, Bankura (Sadar), Gangajalghati and near Khatra police station.

A. Hunday (1949-53) has reported various occurrences of ruby coloured mica in the pegmatites of the following localities (1 to 6).

(1) *Alutia* (23°20′ : 86°52′) : About 800 m. south-west and S. S. W. of the Alutia village, mica of 13.5 sq. cm. size is found in an abandoned prospecting pit.

(2) *Arnakunda* (23°19′ : 86°51′) : The maximum size of mica noted here is 61 sq. cm.

(3) *Rangamatya* (23°23′ : 86°51′) : In the Adli *Nadi* cutting N. N. W. of Rangamatya, clear mica samples with an area of 13.5 sq. cm. were found from the surface.

(4) *Kuleyara* (23°25′ : 86°57′) : A prospecting pit containing mica of 13.5 sq. cm. area in the debris was found S. S. E. of the Kuleyara village.

(5) Crossing of *Kenjakra-Shaldiha road and Dwarkeswar river* (23°16′ : 86°54′) : Mica books of 10 to 13.5 sq. cm. size are found in pegmatites on the surface.

(6) Gonsaidihi (23°33′ : 86°50′) : Mica books ranging in size from 40.6 to 81 sq. cm. are seen in an abandoned prospecting pit.

(7) *Chandipur* (23°34′ : 86°57′) : Mica having sizes from 10 to 13.5 sq. cm. is found in the surface cxposure of a pegmatite.

(8) *Kaduri* (23°22 : 86°50′) : Abandoned prospecting pits and old mines are found near the Bankura-Purulia district border near Kaduri. The maximum size of mica books is 21 sq. cm. with a thickness of 2.6 cm.. After dressing, the size is reduced to 20 sq. cm.. The mica is a clear, ruby muscovite absolutely free from inclusions.

(9) *Pirrabani* (20°19′ : 87°10′) : Muscovite books, clear but somewhat buckled, ranging in size from 40.6 to 61 sq. cm. have been noted at about 800 m. W. S. W. of Pirrabani. Mica over 6.8 sq. cm. in area is found in the *nala* cuttings about 1.5 km. north of Pirrabani village.

(10) *Ramkanali* (23° 20′ : 87° 09′) : Muscovite books averaging four centimetres in thickness and 13.5 sq. cm. in area, occur in the *nala* cutting south of Ramkanali.

(11) *Radhakrishnapur* (23° 20′ : 87° 09′) : Clear muscovite books, 6.8 to 13.5 sq. cm. or more in area, are found near the confluence of two *nalas*, the locality being about 1.5 km. north of Radhakrishnapur village.

(12) *Mujrakundi* (23° 18′ : 87°01′): Clear and soft muscovite books of over 61 sq. cm. in size are collected from a depth of one metre from the surface at a place 1. 2 km. north-west of Mujrakundi village.

(13) *Balidumdumi* (23°18′ : 86°10′) : Mica books found here are similar to those found near Mujrakundi.

(14) *Salbani* (23° 15′ : 87°01′): Muscovite books of over 13.5 sq. cm. in area are found south of Salbani village.

(15) *Khayerbani* (23°19′ : 87°05′) : Muscovite books of over 6.8 sq. cm. in area have been found west of Khayerbani village and near the crossing of a *nala* and a cart tract near Mukundapur.

(16) *Malindesi* (23°19′:86°23′): Clear muscovite books of over 6.8 sq. cm. in size occur in a number of pegmatites west of Malindesi village and in the Gandeswari *nadi* cutting.

(17) *Kulpat-Bankati* (23° 17′:87°01′) : Muscovite books of over 6.8 sq. cm. in area are found in the *nala* cutting 800 m. west and W.N.W. of Kulpat-Bankati village.

(18) *Ladadihi* (23°16′:87°01′) : Mica over 13. 5 sq. cm. in area is found in the pegmatite exposures in the railway cutting, south of Ladadihi village. P. K. Chatterjee (Krishnan, 1958) examined the occurrences of white mica (up to 10 sq. cm.) at Ladadihi and Gosaidih, (23°33′ : 86°58′). The mica blocks after dressing will yield mica up to 2.6 sq. cm. in size.

(19) *Oltara* (23°19′:87°10′) : Muscovite books measuring 6.8 sq. cm. are found in the *nala* cutting about 800 m. W.N.W. of Oltara village.

(20) *Madla Kamdebpur* (23°17′:87° 11′) : Clear muscovite books more than 6.8 sq. cm. in size have been found from north of Madla Kamdebpur village, and 1.2 km. north-west of the village near the crossing of a *nala* and the railway line.

(21) *Kendbana* (23°25′ : 87°06′) : Muscovite books of about seven sq. cm. in size have been found seven kilometres south-west of Kendbana village.

(22) *Gidhuria* (23°23′ : 87°00′) : Muscovite books ranging in size up to seven sq. cm. occur in the *nala* cutting east of Gidhuria village.

(23) *Gopinathpur* (23°22′ : 87°10′) : Muscovite and altered biotite books of about seven sq. cm. in size occur in the pegmatite exposures in the Sali *nadi* section north-east of Gopinathpur village.

(24) *Kadamara* (23°02′ : 87°01′) : Muscovite books, 2.6 cm. thick and ranging in size from 40.6 to 169 sq. cm., are found in pegmatites in the granitic country to the west of Kadamara village.

(25) *Kendasaer* (23°12′ : 86°52′) : Muscovite books of about 100 sq. cm. in area and 2.6 cm. in thickness are found east of the crossing of the Kendasaer-Rajagram and Kendasaer-Kenjakura roads. These micas are stained and somewhat weathered. Mica bearing pegmatites with 6.8 sq. cm. muscovite books are also found on either side of a road running south-east from Kendasaer to the *nala* crossing.

Clear muscovite books ranging in size from 13.5 to 27 sq. cm. were noted in the pegmatites within the soft fine-grained mica-schists in the *nala* sections south-east of Kendasaer village.

(26) *Barut* (23°14′ : 87°01′) : Pegmatites containing muscovite books, ranging from 10 to 27 sq. cm., were noted north-east of Barut village.

(27) *Mahada* (23°02′ : 87°01′) : Muscovite books of 13.5 sq. cm. in size, are found in the pegmatites about 800 m. east Kadmara and N.N.W. of Mahada village.

(28) *Nandigram* (23°13′ : 87°01′) : Muscovite books, clear in thin flakes and ranging over 13.5 sq. cm. in size are found in pink pegmatite veins with a strike N.N.E.—S.S.W. on the northern bank of the Dwarakeswar river to the east of Nandigram village.

(29) *Tentulia* (23°06′ : 86°57′) : Muscovite books 13 sq. cm. in size are found in pegmatites exposed in the Jaipanda *nadi* section to the north of Tentulia village.

(30) *Golakpur* (23°06′ : 86°55′) : Small muscovite books are found in pegmatites about 400 m. E.S.E. of Golakpur village.

(31) *Khakrakanali* (23°01′ : 86°57′) : Pegmatites containing muscovite books of 13.5 sq. cm. in size are found south of Khakrakanali village.

(32) *Kharbani* (23°09′ : 86°44′) : Muscovite books of about 13.5 sq. cm. in size occur east of Kharbani village.

(33) *Kantapahari* (23°09′ : 86°51′) : Muscovite books ranging upto 13.5 sq. cm. in size occur in pegmatites in quartzo-felspathic gneiss exposed in Arkusa *nadi* section south-east of Kantapahari village.

(34) *Gholegore* (23°13′ : 86°52′) : Pegmatite veins in the soft fine-grained mica-schists, east of Gholegore village, contain muscovite books ranging upto 13.5 sq. cm. in area.

(35) *Shyamnagar* (23°06′ : 86°48′) : Mica bearing pegmatites with muscovite books of 6.8 sq. cm. in size occur in the *nala* section S.S.W. of Shyamnagar village.

(36) *Kustara* (23°12′ : 86°55′) : Muscovite books of over 6.8 sq. cm. in size have been noted in the pegmatites about 6.4 km. north of Kustara village.

(37) *Salgerrya* (23°22′ : 86°57′) : Pegmatite exposures about six kilometres south of Salgerrya and on the south bank of Jaipanda *nadi* bear muscovite books about seven sq. cm. in area.

(38) *Nagri* (23°01′ : 86°58′) : Muscovite books, up to 6.8 sq. cm. in area, occur in pegmatites intruding hornblende-and mica-schists in the *nala* south-west of Nagri village.

(39) *Bholarkap* (23°08′ : 86°56′) : Pegmatites, within felspathic gneiss, bearing muscovite books of 6.8 sq. cm. in area, were noted south-east of Bholarkap village.

(40) *Bankata* (23°08′ : 86°44′) : Pegmatites containing muscovite books ranging upto 2.6 sq. cm. in area, occur in the mica-schists along a W.N.W.-E.S.E. direction in the *nala* section south of Baukata village.

(41) *Mahaldanga* (23°05′ : 86°49′) : Pegmatite exposures with small muscovite flakes occur north and south-east of Mahaldanga village and N.N.W. of Brahmadanga village.

Pegmatite exposures containing small flakes of muscovite mica occur at the following localities: About 800 m. north of *Shaerdih village* (23°12′ : 86°49′) : at the crossing of a cart tract from *Dhuludih*

(23°14′ : 86°58′) to *Pachirdanga* (23°15′ : 86°57′) village at the north bank of the Dwarkeswar river ; in the *nala* sections north of *Nowadihi* (23°05′ : 86°46′) and north-west of *Ranga* village (23°05′ : 86°47′) ; in the paddy field W.S.W. of the southern *Kaliapathar* village (23°04′ : 86°52′) N.N.W. of *Jambedya* village (23°07′ : 86°59′); in the quartz vein west of *Bagdiha* village (23°10′ : 86°47′) ; in the *nala* south of *Maukhuri* village (23°09′ : 86°59′) ; in the *nala* south-east of *Tisra* village (23°14′ : 86°52′) ; in the *Purundihi* village (23°14′ : 86°58′) : old excavations for mica are noticed and it is said that fair sized muscovite books were found within a depth of one metre ; south-west of the *Dhagaria* village (23°12′ : 89°56′) ; east of the *Bansdihi* village (23°07′ : 86°53′); in the paddy field north of the *Churamanipur* village (23°07′ : 86° 54′) ; in Jaipanda *nadi* section of the *Madhunia* village (23°06′ : 86° 57′) ; east of the *Jamardihi* village (23°14′ : 87°00′); in the neighbourhood of *Mahalbani* (22°49′ : 86°56′) : north *Jharia* (22°47′ : 86°55′) on both sides of the Raipur Phulkusma road near the laterite exposures. Superficially stained muscovite books range over 13.5 sq. cm. in size ; in Kasai river section E.N.E, of *Malidanga* (22°48′ : 86°56′) ; east of *Paurari* (22°49′ : 86°56′); north-west of *Gobindapur* (22°50′ : 86°56′) ; and north-west of *Bagakhulia* (22°57′ : 86°57′) on the hillock (4370 m.), pegmatites exposures trending mostly N.N.E.-S.S.W. and some measuring 91 m. long and 27 m. wide contain greenish and clear muscovite flakes ; in the small *nala* about 800 m. west of *Maukura* (22°52′ : 86°57′); 800 m. W.N.W. of *Rengurbandh* (22°56′ : 86°57′) ; and 800 m. north of *Rajaband* (22°56′ : 86°57′), a number of pegmatite exposures, with a N.N.E.-S.S.W. strike, and some measuring 122 m. long and upto 11. 3 m. wide include small books fo muscovite mica ; west of *Kadamara* (22°57′ : 86°57); around *Katar* (22°59′ : 86°57′) village ; in the *nala* section north and north-east of *Parashidanga* (22°58′ : 86°59′); in the Mura *Jhor* section south of *Khayerbani* (22°58′ : 86°58′) ; 800 m. west of *Jarka Pakasara* (22°59′ : 86°59′); south-east of *Bhaladihi* (23°00′ : 86°57′) ; around *Tiring* village (22°59′ : 86°57′) ; one kilometre north of *Kharkhari* (22°57′ : 87°00′) and also to its east ; 800 m. N.N.E. of *Nekrasonda* (22°58′ ; 86°59′). in the Mura *Jhor* section south-east of *Kurnipahari* (22°58′ : 86°56′) ; in the *nala* section north of *Kalapathar* (22°47′ : 86°47′); north-east of *Kapashera* (22°47′ : 86°57), clear muscovite books of 5.2 sq. cm. in size are .alleged to have been recovered by the local people ; west of *Doldaria* (22°57′ : 86°00′) near the small *nala* section ; *Mukdapur* (23°01′ : 86°42′) ; *Deuch*

(23°25′ : 87°15′); in the *nala* section between *Atbhaichandil* (23°07 : 87°00), *Benagari* (23°07′ : 87°00′) and *Kharbani* (23°07′ : 86°59′); near *Binodpur*, (23°03′ : 86°58′); *Nayada* (23°04′ : 86°57′); in the Dwarkeswar river section north of *Chhatardih* (23°14′ : 87°00′); in the Jaipanda *nadi* section west of *Chaitandihi* (23°09′ : 86°54′): from *Kaludih* (23°13′ : 86°59′); *Kharia* (23°13′ : 86°55′); *Menjua* (23°07′ : 86°55′); in the Dwarkeswar river section north of *Santor* (23°13′ : 87°08′).

Hunday (Krishnan, 1954) is of the opinion that detailed prospecting of the pegmatites which contain fair sized books of mica near the surface may be undertaken to ascertain if the quality and size of the muscovite books improve in depth. Most of these muscovite books range in size upto five square centimetres near the surface.

MIDNAPUR DISTRICT

Muscovite-bearing pegmatites occur in crystalline gneiss and schist near *Shiarbinda* (22°45′ : 86°40′), *Chakadoha* (22°46′ : 86°39′) and *Dhiukia* (22°47′ : 86°37′) (Dunn and Dey, 1937).

DARJEELING DISTRICT

Occurrences of pegmatites in the Archaeans of the district may contain flakes of muscovite, but not much is known about them.

Small sized clear muscovite occurring in West Bengal may be put to some use after grinding them wet and dry, and making them into 'micanite'. Some clear flakes ranging from 10 to 13 sq. cm. in size may be used in the electrical industries. India's first micanite factory has been opened in Kodarma in Bihar. Recently, a process for the preparation of insulating bricks from waste mica has been found at the Central Glass and Ceramic Research Institute, Calcutta. A new process for wet ground mica has recently been patented by the Indian School of Mines, Dhanbad, Bihar.

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CHAPTER XVII

MINERAL FERTILISERS

Mineral fertilisers are important raw materials in a predominantly agricultural country.

Fertilisers provide the soil with nitrogen, potash, phosphorus, calcium and other elements.

Nitrogen

The chief sources of nitrogen are nitrate of soda, nitrate of potash, sulphate of ammonia and calcium cyanamide.

Nitrate of Potash :— The *reh* or *kalar* efflorescene of alkali salts deposited on the soil of North Bihar is an important source of nitrates, and the same types of salts may be obtained from the soils of the contiguous parts of North Bengal. The efflorescence of salts in the Sunderban area may also be analysed to know about their salt contents. Khedkar (1950, p. 181) has reported that crude saltpetre (Kuthea) extracted from the soils of the Damodar Valley contains about 66 per cent. potassium nitrate, and upto 35 per cent. sodium chloride with some sodium sulphate and magnesium nitrate.

Sulphate of Ammonia :—Ammonium sulphate is manufactured as a by-product during the distillation of coal in the coking plants. There is also an immense scope to manufacture it in West Bengal from the coke oven plants of IISCO and the Durgapur Iron and Steel Plant and the Durgapur Coke Ovens Plant. Out of the 14 coke plants in India, four, including one coal gas plant, are situated in West Bengal and seven in Bihar. The average ammonia content of the ammonium sulphate is about 25 per cent. The consumption of ammonium sulphate as a fertiliser is gradually increasing in India. Ammonium sulphate can also be synthetically produced from coke by the Haber Bosch process.

Calcium cyanamide :— Calcium cyanamide made from calcium carbide is an important fertiliser. For the manufacture of calcium cyanamide a pure limestone with iron at less than 0.20 per cent. and with total combined impurities less than two per cent. (permitting a low percentage of quartz) is required. Some of the calcareous tufa deposits of the Darjeeling and Jalpaiguri districts may be utilised for this purpose.

Potash

Besides the nitrate of potash found in certain soils, the other sources of potash are potash felspar, blast-furnace dust and cement-kiln gas.

Potash Felspar :— Large quantities of potash felspars are usually available from various pegmatites ramifying the Archaean terrain of the State. The mica-bearing pegmatites contain a certain amount of potash felspar.

Blast-furnace dust :— The dust deposited in stoves and boilers and at the base of the chimneys of iron-smelting blast-furnaces is usually high in potash. This source of potash may be tapped from the existing blast-furnaces in the State.

Cement-kiln gases :— Potash is also available in the flue dust from cement-kilns, but at present there is no cement factory in the State.

Phosphate

The important sources of phosphate are apatite, bones and basic slag from the smelting of basic steel. Of these, some amount of apatite, bones and basic slags are available in the State.

Apatite:— The resources of this mineral in the State is very meagre. The lamprophyres and mica-peridotite intrusives in the coalfields of West Bengal may provide a good source of apatite (Banerjee, 1953).

Bones :— The material is available in considerable quantity in the State. Super-phosphate for fertiliser can be prepared from these bones and from bone-meal, in which phosphates form an important constituent, by treating this with sulphuric acid.

Basic slag :—About three per cent. P_2O_5 is present in open hearth slag and six per cent. in Duplex slag. These slags after grinding may become useful as a fertiliser.

Miscellaneous fertilisers

Gypsum :— There is no other deposit of gypsum in the State, excepting the only reported occurrence of selenite (gypsum) near Chainpat and Dari Ajodhia (22°37′ : 87°49′) villages in the Midnapur district.

Limestone :—Lime, under certain conditions, is beneficial to the soil, especially when accompanied by other fertilisers such as potash,

Prospects and Development

Soil conservation and nutrition go hand in hand with any planned programme for agricultural production. The State of West Bengal, in particular, having a major area of land covered by soil, naturally deserves a great attention in this endeavour.

The soils of the State are generally reported to be deficient in nitrogen, organic matter and lime, and as such artificial nutrition is required through the use of chemical fertilisers.

It is reported that the existing demand for nitrogenous fertiliser can be met from internal production, which is currently about 2,200 tonnes.

In order to meet the demand for chemical fertiliser in the State, the establishment of an 'Urea and Nitro-phosphate Plant with an annual capacity of 81,000 tonnes, and installation of suitable units for superphosphate in Calcutta and Durgapur have been suggested by the 'National Council of Applied Economic Research'.

With the installation of carbonisation plants and related coal-based chemical industries as envisaged during 1961—71, the quality of soil in the state will be enriched by 150,000 tonnes of nitrogen and 75,000 tonnes of phosphate (P_2O_5), by the use of this type of manure.

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CHAPTER XVIII

MINERAL SPRINGS

General

Mineral springs are numerous in many parts of India, and many of them possess medicinal and radioactive properties. In West Bengal, there are a few mineral springs in the Purulia, Birbhum and Darjeeling districts. The curative value of some of these waters for certain diseases has long been recognised. These springs are held sacred by the Hindus and temples have been erected close by and baths are built in these springs.

Late P. K. Ghosh, of the Geological Survey of India, investigated the radioactive and medicinal properties of many of these springs in India with a view to establish 'SPAS'. The Geological Survey of India is also engaged at present in carrying out investigations on some of these more prospective mineral springs.

Localities

PURULIA DISTRICT

(1) *Tantloi* (23°41′ : 86°44′): There are three hot springs Tantloi No. 1, 2 and 3, west of the Raniganj coalfield. These are situated by the Damodar river. The springs appear to occur along a fault zone, and that fault zone may be a continuation of the major east-west fault zones of the coalfields. The temperature of the water is about 60°C, and it contains CO_2 and H_2S gases. The water is sulphurous and slightly chalybeate. The spring water is reported to cure skin diseases, digestive disorders, rheumatism and dyspepsia.

(2) B. C. Roy (1938) has recorded several perennial springs in the *Panchet Hill* (23°37 : 89°46) area. These are mostly found within the Archaeans close to the coalfields.

BIRBHUM DISTRICT

(1) *Bakreswar Group of Springs* (33°52′ : 87°02′): This group of hot springs is situated on the right bank of the Bakreswar stream, 1.6 km. south of the Tanipara village. The nearest town is Suri about 12 km. east of the spring which is connected by a metalled road. There are five masonry tanks collecting spring water for bathing purposes.

The two important springs in this group are (i) Agnikund and (ii) Brahmakund. The data known about these springs are given in Table 16 below :—

TABLE 16

		Agnikund	*Brahmakund*
1.	Temperature	71°C	42°C.
2.	Rate of flow	5,500 litres per hour	5,500 litres per hour
3.	pH Value	9.3	——
4.	Mineral content Total ions or mineral concentration	325. 8 parts per million	——
5.	Sulphate ions	26.0 p.p.m.	——
6.	Chloride ,,	85.0 ,,	——
7.	Sodium ,,	156.0 ,,	——
8.	Calcium ,,	8.6 ,,	——
9.	Gaseous content CO_2	present	not observed.
10.	H_2S	present	not observed.
11.	Radons % (mMc per litre)	2.8058	0.7918
12.	Therapeutic value	For both the springs : Cures skin diseases digestive disorders and rheumatism, and induces appetite.	

Chowdhury and others (1964) studied the geochemistry of the Baloreswar springs and found that the temperature of the water varied only moderately in different springs. The maximum temperature recorded was 66.6°C ; pH varied from 8.6 to 9.3, soluble silica was about 80 p.p. m., H_2S (maximum) about 2 p.p.m., major cation : Na with very low Ca and Mg ; major anions $Cl > CO_3 > HCO_3 > SO_4 > F$.

Radioactivity of these springs :— It is said that spring water, in general, owes much of their curative properties to radioactivity. The radioactivity of the waters is due to the presence of radon in solution, the radon being derived from the disintegration of thorium and uranium bearing minerals present in the rocks, through which the waters circulate. Most springs and some well water contain traces of radon, but very few contain radium salts in solution. Spring waters, except those which are permanently radioactive, lose natural radioactivity when bottled for any length of time, and at the end of a month or so radon disappears. Such waters are called radio-emanative.

The waters of the Agnikund are strongly radioactive (Ghosh, 1948), the radon content being 2.80 mMc per litre which can be compared with the content of the Borla Spring, Sweden (radon content 2.912 mMc per litre). The water from Borla cures rheumatism, anaema, and gout. The waters of the Brahmakund are feebly radioactive (radon content 0.79 mMc per litre) and can be compared with some European waters like that of Markany (radon content 0.36 mMc per litre) and of Droitwitch (radon content 0.21 mMc per litre) which are utilised chiefly for its medicinal constituents.

Darjeeling District

The Himalayan springs are probably related to local thrusts and faults. P. K. Ghosh (1948) noted the existence of zones of crushing and brecciation at the site of the springs.

(1) *Mechi* (26°50′ : 88°30′) : This spring has been mentioned by La Touche (1918). The water is clear with deposits of iron oxide. It is said to be efficaceous for rheumatism and skin diseases.

(2) *Minchu* (27°06′ : 88°18′) : The following description of this spring is given by La Touche (1918). The spring is situated at eight kilometres from Darjeeling. According to Piddington the water is carbonated, sulphurous and chalybeate. It contains 0.436 gm. Fe_2O_3, 0.37 gm. sulphur and 0.132 gm. of salt per 4.55 litres. It is said to be similar to that of Bath and one of the Harrogate springs of U. K. and is reported to be efficacious in gout, rheumatism etc.

(3) *Jalpaiguri district* : The spring which occurs near Buxa about five km. from Tashigaon, is reported by the local people to cure skin diseases.

(4) *Bankura district :* There are two cold springs, one at the south-western flank and the other at the eastern flank of the Susunia hill (439m.).

Classification

Ghosh (1948) classified the spring waters into (a) Radioactive and (b) Medicinal types. The Agnikund spring of Bakreswar near Suri in the Birbhum district can be compared favourably with some of the radioactive waters of foreign countries.

The medicinal value of the waters is judged by the amount of salts in the spring water as compared with those present abroad. Various types of waters may be recognised in India.

1. (a) Sulphur waters (cold), Trinkquelle type.
   (b) Sulphur waters (Warm), Aix-les-Bains type.
2. (a) High carbonate waters, Appolinaris type.
   (b) Low carbonate waters, Evian water type.
3. Chloride (saline) waters, Marienquelle and Leamington type.
4. Chloride waters (mild).
5. Waters which do not resemble known European waters. In West Bengal, the waters are mostly of Aix-les-Bains type.

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CHAPTER XIX

MINERAL PIGMENTS (OCHRES)

Ochres are natural mineral pigments consisting of a clay base with iron oxide generally containing calcium and barium compounds in addition. Yellow ochre has a clay base permeated with hydrated ferric oxide; red ochre contains a clay base with red ferric oxide. Red oxide is a soft ferric oxide with little or no clay base. Brown earth with small amount of manganese oxide yields the colours, amber and sienna. Carbon phyllites are often used for black pigment. These are associated with the Dalma lava, with the lava and tuff of the Iron-Ore series and with slate and phyllite of Daling series in the Darjeeling district. Black Carbon phyllite occurs in the southern part of Purulia and also in certain places in the Bankura district. Some ochre may be associated with clay in the Rajmahal hills.

Properties—Ochres have various shades of colour which are permanent and have a good covering power. Oxide pigments are good driers, durable, inert and possess a good spreading power. The brown earths comprise amber, sienna and a variety of other tints.

Uses :—Ochres are extensively used for manufacture of paints, oil-cloth, linoleum, paper and pigment, in ceramics, in cement and rubber goods. Oxide pigments are widely used for painting exposed iron and steel works, such as bridges, ships, railway coaches etc.. Brown earths are used largely in printing, as artists' colours and as stain and colour fillers.

Specifications

Certain physical properties as (i) state of aggregation, pulverulence, fineness of particle size and absence of hard gritty particles, (ii) the type and purity of colour, and (iii) the strength of staining powder of the ground pigment determine the use of any ochre in the paint industry.

Specification for ochre for paints :

According to specification of the Indian Standards Institute, the dried pigment should contain not less than 35 per cent. of ferric oxide (Fe_2O_3) and not more than five per cent. of calcium compounds expressed as CaO (calcium oxide).

The material should consist entirely of natural ochre, the colour of which should be due wholly to inorganic compounds of iron and should

not contain any organic colouring matter. The material should also conform to the requirements given below :

Characteristics	*Requirements*
1. Volatile matter	Not more than one per cent..
2. Residue on sieve (No. 230 ASTM)	Not more than 0.5 per cent..
3. Oil absorption	Within 5 of the approved sample.
4. Colour	Close match to the approved sample.
5. (a) Staining power	Not inferior to the approved sample.
(b) Tone	Equal to the approved sample.
6. Matter soluble in Water	Not more than one per cent.
7. Acidity	Not more than 0.1 per cent.
8. Alkalinity	Not more than 0.1 per cent.

Specification of natural red oxides of iron for paints.

The dried pigment shall contain not less than 70 per cent. iron oxide (Fe_2O_3). The material should be a natural product, the colour of which should be wholly due to inorganic compounds of iron. The material should also conform to the following requirements :

Characteristics	*Requirements*
1. Volatile matter	Not more than 0.5 per cent..
2. Residue on sieve (No. 230 ASTM)	Not more than 0·5 per cent..
3. Oil absorption	Within 5 of the approved sample.
4. Colour	Close match to the approved sample.
5. (a) Staining power	Not inferior to the approved sample.
(b) Tone	Equal to the approved sample.
6. Matter soluble in water	Not more than two per cent.
7. Alkalinity	Not more than 0.1 per cent.

The entire Indian production of the red oxide of iron is consumed indigenously, mainly in the paint industry.

The State of West Bengal has sporadic occurrences of mineral pigments in the form of grey and mottled clays, limonitic ores, carbon phyllite, and of vermiculite in some of the western and northern districts. The localities are as follows :

Burdwan District

Ochres and bluish grey and yellow mottled clays suitable for use as pigments are associated with lateritised sandstones and grits of the Durgapur beds in the eastern part of the Raniganj coalfield (Krishnan, 1960).

MIDNAPUR DISTRICT

Some yellow and red ochres are found north-east of *Laubani* (22° 36′ : 86° 41′).

PURULIA DISTRICT

(1) Ochre, which is used locally as a colour wash, is found near *Rajabasa* (22° 49′ : 86° 24′).

(2) B. C. Roy (1938) reported that the red shaly bands, 61 cm. to 1.83 m. thick and horizontally bedded and gently dipping towards north, occur around Ranimahal (472m.) in the *Panchet* (23° 38′ : 86° 45′) area. They are suitable for use as red ochre. These are associated with flagstone of Panchet stage. A sample on analysis gives 63 per cent. metallic iron. The colour is upto the specifications required.

M.K. Sen (1955, p.180) has found red clay bands, 7.8 cm. to 23 cm. thick, intercalated with brown ferruginous sandstone and carbonaceous bands of Panchet stage at a place having geographical co-ordinates as 87° 01′ : 23° 35′. The red clay beds are usually 1 to 1.83 m. apart and contain about 22. 21 per cent. iron.

BANKURA DISTRICT

Occurrences of carbon phyllite have also been found in the Kasai river section in the Bankura district about 6 to 8 m., downstream from the Kankshabati Dam on Kasai river and in adjacent areas, after an almost right angle bend of the river in sheet 73 J/13 (Hunday, 1949-53).

Vermiculite occurrences found in a number of localities by A. Hunday have a scope of utilisation in the paint industries and heat insulation. The sporadic occurrences of iron-ores, specially the hematites near Porapahar can also be utilised in the paint industry.

The records of production of ochre in the State during 1956-62 are as follows :—

	1956	1957	1958	1959	1960	1961	1962
In tonnes	410	172	184	1,067	618	466	308
Value in Rupees	—	—	—	Bankura : Rs. 3,000/- Midnapur : Rs. 5,300/-	Bankura : Rs. 7,000/- Midnapur : Rs. 8,000/-	Rs. 8,000/-	Rs. 5000/.

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CHAPTER XX

OIL AND NATURAL GAS

Petroleum or mineral oil is essential for the development of a country. It is also a strategic raw material. It is estimated that petroleum supplies about 14 per cent. of the total energy consumed in India. Until recently, the Digboi oilfield of upper Assam was the only oil producing area in India. The exploration of this field started as early as 1866. The Nahorkatiya oilfield in the Brahmaputra valley of upper Assam was discovered later. The prospects for finding oil in the vast and widespread sedimentary basins of India attracted private enterprisers, and the Standard Vacuum Oil Co. (now ESSO) started exploration for oil in the Bengal basin since 1949.

The recent findings by Hunday (1954) of Tertiary rocks of various places in the western districts (*viz.* Bankura, Midnapur, Birbhum) of the State suggesting their possible correlation with the beds overlying Baripada beds (Miocene) in Orissa and Tipam beds of Assam may prove to be of significant importance in this regard.

In 1955, the Government of India established the 'Oil and Natural Gas Directorate' which, in 1956, was converted into a 'Commission'. The Government of India came into the field jointly with the Standard Vacuum Oil Co. for oil exploration in West Bengal. The company carried out the prospecting for the first five years. The total investment by the Indo-Stanvac project upto the end of June 1960, was more than Rs. 75 millions, of which 75 per cent. was borne by the company and the remainder by the Union Government. But it is disappointing that no oil or gas field has been discovered in West Bengal. In the early part of 1960, the Stanvac appointed consultants to investigate into the causes of failure, and the consultants gave the opinion that there are greater chances of tapping gas in this region than oil. In September 1960, the Stanvac suspended its search for oil in West Bengal. The Oil and Natural Gas Commission have now taken up explorations in areas not in the Bengal basin.

Prospecting for oil in West Bengal

During 1951-52 the Standard Vacuum Oil Co. (through M/s. Fairchilds) had conducted an extensive reconnaissance aeromagnetic survey of about 89,000 sq. km. (64,372 flight km.) of the Bengal basin. Subsequently, on the results of this initial reconnaissance survey, an area of about 25,900 sq. km. was taken on lease by the

Company for intensive prospecting work. During 1953-55, the Company made 12,000 gravity observations, and exploded 18,800 seismic shots (in about 4,828 line km. of seismic profiles) within the leased area in West Bengal. Exploratory drilling commenced from April 1957, and a total of 28,870 m. at 10 different boreholes was drilled by 1960. The exploratory oil-wells at Burdwan (23°14′22″ : 87°56′00″), Galsi (23°27′ : 87°39′) and Jalangi (24°04′ : 88°38′), have brought out valuable information about the sub-surface geology, palaeogeography and the structure of the Bengal basin.

The Bengal Basin

The West Bengal basin (including parts of coastal Orissa and the Sunderbans) approximately covers an area of 77,700 sq. km.. To the north, it is bounded by a buried ridge aligned east-west between the Rajmahal and the Garo hills, while on the west the small exposures of the fossiliferous Miocene limestones and clays form the edge of the basin, running southward from the Rajmahal hills through the western districts of West Bengal.

Thick mantles of alluvium of the Ganga and the Brahmaputra conceal the older sediments in the basin. The thickness of this alluvium cover is about 300 m. in the Rajmahal area, about 73 m. in Galsi, 216 m. in Jalangi, 334 m. in Burdwan and about 610 to 914 m. in the Barasat-Madhyamgram area. The thickness increases towards the east and south-east, and it is a few thousand metre at Bogra in East Pakistan where Gondwanas have been struck at a depth of about 2,438 m.

Rock formations ranging in age from late Cretaceous to Recent, including all the major divisions of the Tertiary, have been recognised in this basin. These include marine, estuarine, brackish, and continental types of sandstones, shales, and the fossiliferous limestone, some of which are characterised by the presence of *Nummulites* and *Assilina*. The sediments rest on basic lava flows presumably of late Jurassic age, and have a thickness of 3,292 m. at Jalangi, 2,579 m. at Burdwan and 1,159 m. at Galsi. The formations show that the basin occupied the site of a former sea which made several transgressions and regressions from the south since late Cretaceous time. The sea was the forerunner of the present Bay of Bengal, and extended as far north and north-east as Assam.

The geophysical survey of the Bengal basin has indicated gentle easterly and south-easterly dips of the buried sediments, which are

affected by normal dip and strike faults. These sediments are practically unaffected by folding. The sediments become thin towards the western edge, which forms a hinge line bordering a gulf. The beds attain a thickness of more than 6,096 m. with varying degrees of homoclinal dips towards the south and south-east.

Natural Gas

Emission of gas has frequently been reported from dug wells, tube-wells, or from low marshy land by the villagers from many places in the deltaic region of West Bengal. Most of these gases are found to be marsh gas originating from the decomposition of organic matter in the deltaic and coastal alluvium. One such gas emission from a tube-well when sunk upto a depth of 205.8 m. at Gopimohanpur in the Tamluk sub-division of the Midnapur district has recently been investigated by the Geological Survey of India (Krishna Rao, 1961). The analysis of the gas indicates that it consists mostly of methane which is commonly known as 'Marsh Gas'. The other constituents are nitrogen, oxygen, carbon dioxide, unsaturated hydrocarbon and carbon monoxide.

Natural gas in small quantities was found in four test wells sunk by the Stanvac. And according to them there are greater chances of tapping gas in this region than oil. Several gas fires have recently been reported from the boring of tube-wells. In the contiguous deltaic terrain in East Pakistan, one such occurrence was reported from the village Bilmamudpur, three kilometres from Faridpur (East Pakistan). According to the report, natural gas, gushing from a 27.4 m. deep well burst into flames and scared away the workmen engaged at work. (The Statesman, p. 9, dt 16-4-62). The possibility of getting natural gas in West Bengal in commercial quantities like that of Sui in West Pakistan is yet a conjecture which can only be confirmed by drilling.

Uses and Consumption

Oil provides the much needed energy not only for internal combustion engines, but is also used for lighting and in stoves. It is also used for the generation of power, as in Gujarat. It has been found that petroleum is used for the generation of 14 per cent. of energy in this country, and the cost of such power generation has been estimated at about 4P. per unit. It works out to be a little more than coal which is 3P. per unit.

Apart from its use for the generation of electrical energy,

natural oil and its products are utilised in many other industries, such as paint, plastic, polishing and in the manufacture of gramophone records, in asphalt, paraffin, lubricants, liquid soaps, explosives, printing inks, adhesives, velvets and other fabrics, insecticides, detergents, dyes, medicines, photographic films, cellophane, special greases, synthetic rubber, rust preventives, etc.

Petroleum is also used as an illuminant, and as fuel oil and in ships and locomotives and for the generation of heat. Gasoline is used in automobiles, trucks and in aeroplanes as fuel, high speed diesel and motor spirit. Its other uses are in the manufacture of solvent oil, sleeper oil, turpentine, wood oil, mineral jelly and asphalt.

Oil has greater calorific value than coal and is more easily transportable and combustible than coal and has no other substitute as a lubricant.

The consumption of oil products in India during 1960 and 1961 was about 7·6 and 8.3 million tonnes respectively, which is estimated to increase to about 14 million tonnes with the growth of industries, etc. by the end of the Third Five Year Plan.

Synthetic Petroleums

Recently the Geological Survey of India investigated the quariable coal deposits in East Raniganj Coalfield. The reserves of such coal (the ash content varying from 12 to 20 per cent.) upto a depth of overburden of three times the thickness of the seam (maximum thickness noticed 13.4 m.) are about 356 million tonnes in the Taposi-Jambad-Kajora and Ondal areas. On the basis of available information the establishment of a synthetic Oil Plant in Ondal has been recommended by the Geological Survey of India.

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CHAPTER XXI

SALT

Common salt (Nacl, with 39.4 pcr cent. of Sodium and 60.6 per cent. of chlorinc) is quite common and widc in its distribution. Apart from its occurrences as bedded deposit and in association with sand in dried up lakes, it is found to constitutc 2.7 per cent. of sea water and forms the total of 77.8 per cent. of the solublc matter present in sea watcr.

It is estimated that about 5.4 kg. of salt is consumed by each individual in a year.

However, in addition to the above uses, salt has manifold industtrial usages ; in packing and in prescrvation of meat, fish, hide, skin, wood, in dairy farming, in bakcries, in soap and dye stuff manufactures, finishing fabrics, refrigeration, glazing of earthenware ; in the manufacture of artificial rubber ; for soil stabilisation, for the production of sodium carbonatc (soda ash), caustic soda, hydrochloric acid, metallic sodium, sodium sulphate, sodium sulphidc, sodium cyanide, sodium peroxide, synthetic indigo ; for cattle feed, for treatment of hay and as a fertiliser in certain crops ; in explosives, in medicines etc.

The demand for salt is steadily increasing not only in relation to the growing population but also in its varied utilisation in chemical and related industries which have programmes of rapid expansion under the Five Year Plan projects.

In the State of West Bengal, salt industry occupies an important position in the mineral production of the State. In fact, next to coal, salt can claim the highest position in the value of production among the other minerals produced in the State.

The State has enormous potential reserves of sea salt. Common salt manufactured from sea water was initiated as an experimental measure as far back as 1931 in the districts of 24 Parganas and Midnapur. Later in 1933, two factories, one at Sandhiacha near Contai, in the Tamluk sub-division (Tamluk : 22°18′ : 87°55′) of the Midnapur district and the other at Kadua was started by the Premium Salt Manufacturing Co. which produced at the begining a few kilogrammes of salt.

Salt is manufactured from saline earth which is impregnated with salt in contact with sea water. The saline earth is scrapped and lixiviated with water and then filtered. The brine is then boiled, using coal as fuel, either in nests of small earthen vessels or in shallow iron pans.

The possibility of manufacturing salt along a wide stretch of the Contai seaboard, is immense. At present the State is dependent on the south and west coasts of the country for its requirement so the large scale manufacture of salt in the Contai area will greatly relieve the State, and stabilise the Calcutta Salt market (The Statesman, 11th April, 1962).

There is one type of intrazonal soil in West Bengal, *i. e.* saline soils. Alluvial soils along the coast, particularly in the sunderban area show *white efflorescences of sodium chloride, as they are impregnated with* this and other salts by tidal estuaries (Chatterjee, 1949).

The production of salt in the State from 1950 to 1962 is given below :—

Production	*(in tonnes)*	*Value (in Rupees)*
1950	2,575	1,68,110
1951	1,978	1,25,900
1952	2,055	1,10,000
1953	6,836	2,96,811
1954	4,483	2,70,000
1955	5,804	2,92,000
1956	9,253	4,41,000
1957	9,182	7,09,000
1958	8,471	3,64,000
1959	7,688	3,08,000
1960	10,450	6,36,000
1961	6,100	4,60,000
1962	7,300	6,50,000

In India, salt is manufactured mainly by the Salt Department of the Government and only a limited amount is produced by the private sectors.

For making the country self-sufficient in respect of these salts for industrial purposes, the country has been divided into the following five contiguous zones. The State of West Bengal is grouped in the Zone No. 4.

Zone—1	Comprising	Madras and Kerala.
Zone—2	,,	Andhra Pradesh and Mysore.
Zone—3	,,	Maharashtra and Gujarat.
Zone—4	,,	Orissa, West Bengal, Assam, Bihar, and Eastern Parts of M.P.
Zone—5	,,	U.P., Punjab, Delhi and Rajasthan.

As the salt industry in the State ranks second in the mineral production in West Bengal the State deserves every encouragement for promoting its expansion.

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CHAPTER XXII

SILICA

Sand

Large quantities of sands of various specifications are used in different constructional works and in a wide variety of industries. No statistics of its production are available.

Sands occur as detrital deposits. In West Bengal these are usually found along the stream beds, underneath a thin cover of soils and clays in certain parts, along the sea-beach forming coastal sand dunes ; as hill-wash, along the foot hills of the Himalayas, as loamy sands along the northern bank of the Ganga, and as sandy loams covering alluvial plains in North Bengal. The soil with grain size ranging from one-half to five millimetres are generally treated as sand. Large grains with corresponding increase in size pass into grits and gravels. Sometimes soft friable sandstone which can be easily crushed is used as a substitute for sand. Quartz veins and pure quartzites after proper crushing may also be used as high grade silica sands.

Uses and Properties

Sands require some treatment before they are used for certain purposes. It may be sieved through a series of screens ; washed to remove clay materials, mica, and organic matter particularly when a high degree of purity is required.

The major use of sand in West Bengal is for stowing in coal mines. For this purpose, grain size and purity are of little consequence.

Clean and angularly grained sands are preferred in mortars and concrete for buildings and construction. No rigid specifications are required for use in road construction.

Purity and sizing are essential in glass sands. Iron oxide is an undesirable impurity, and it should not exceed 0·02 per cent. for colourless glass. Green bottle glass is obtained from inferior sand rather high in iron (above one per cent.). Alkalies are not deleterious as they have to be added to the mixture in any case. The presence of alumina has to remain within reasonable limits for glasses where a low coefficient of expansion, increased hardness, brilliancy and strength are required. Both alumina and magnesia increase the viscosity of the glass melt, requiring a higher temperature of fusion. It is preferable that the grains should be around 0.4 mm. in diameter ; and the

variations, from very coarse material to very fine in any particular sand used should be avoided. Sieving may reduce the extremes of granularity to a minimum. A coarse sand takes more time for fusion of the batch. Glass sand of the necessary composition is rare not only in West Bengal, but also in India. They are commonly obtained by crushing friable pure sandstones, or quartz and vein quartz.

Moulding sands required by foundries must have special properties like cohesiveness to retain shape, sufficient refractoriness to withstand fusion in the presence of the molten metal and sufficient permeability to allow for cth escape of gases. Coarser sands are generally used for large castings, and the moulding sand mixture also varies for the type of metal to be cast. For iron, good cohesive property of the sands is required ; a high quality is not demanded. For steel castings, a good quality fine sand with special binders such as bentonite is used.

A high grade sand is necessary for lining and patching certain furnaces, cupolas, ladles and vessels used for holding molten metal.

A very pure quartz sand of even grain size is essential for the manufacture of ferro-silicon.

A very pure silica sand is necessary for the manufacture of refractory silica bricks and for use in ceramic ware. Accordingly, detrital sand is rarely used, and crushed sandstone or quartzite is the main source. For ceramic purposes, the iron content of sand must be less than 0.05 per cent.

Sand for filtering water should have even sized grains and be free from clay and organic matter.

Sand used as abrasive must be angular or rounded and not impure. For sand paper, crushed sand is required. Very pure quartz sand is essential for the silicon carbide or carborundum.

Finely ground sand also used as filler in paint, in special plasters, grit for poultry, tooth pastes, cosmetics and dental powder, for frosting glass, in soap and polishes. Material of a high purity is required for these purposes ; and such is generally obtained from quartz-veins, quartzite or friable sandstone.

Distribution

River sands : Large quantities of sands are available from the beds of many rivers flowing in the western and northern areas of the State.

Sands of the Damodar and the Ajoy rivers within the Raniganj coalfield are in great demand at present for stowing in collieries.

According to the reports of the Indian Coal Board the following are the figures indicating the amount of sands used for stowing purposes during the respective years.

		Sands used for stowing purposes.
1961-62	...	7.61 million tonnes.
1962-63	...	9.27 ,, ,,
1963-64	...	11.46 ,, ,,

S. Banerjee of Geological Survey of India has estimated a reserve of 227.6 million tonnes of sand excluding about six per cent. clay beds in the Damodar river between Longitudes 87°07′ and 87°11′, and 87°15′30″ and 87°17′30″. Sand reserves in the Damodar river from its junction with the Barakar river to Pinjrapole (23°33′ : 87°14′) had been estimated at 589.3 million tonnes by the G.S.I. in 1946-48 (Dutt, A.B., 1950).

A reserve of 294.64 million tonnes of sand in the Ajoy river between Longitudes 87°03′ and 87°21′ had been estimated by the Geological Survey of India in 1946-47, and recently S. Banerjee of G. S. I. has found a sand reserve of 92 million tonnes in the Ajoy river between Longitudes 87°08′ and 87°13′; and 87°15′30″ and 87°17′00″.

S. Banerjee (1960) has estimated the total sand reserve as 1,091 million tonnes in the Damodar and the Ajoy rivers within the specified areas in the Raniganj coalfield, and the total annual replenishment of sand in this portion of the Damodar river has been worked out by him about at 10 million tonnes.

Most river sands are rather impure. But occasionally fine-grained, and the comparatively pure sands found in some portions of the river may be used for producing cheap glass such as green bottle glass. The sand from Subarnarekha, Barakar and Damodar is mostly coarse, and requires crushing before use. The analyses of sand from the Ganga near Rajmahal (No. 1), and from the junction of the Barakar and the Damodar rivers (No. 2) are given below (Dunn, 1941, p. 134) :—

	No. 1 in %	No. 2 in %
SiO_2 . .	83.31	80.57
Al_2O_3 . .	7.45	10.25
Fe_2O_3 . .	1.95	2.04
Mn . .	0.20	0.42
CaO . .	2.95	1.57
MgO . .	1.02	0.66
Alkalies (by difference)	2.37	4.71
H_2O	0.75	0.22
	100.00	100.00

River sand is also excavated and used for various constructional purposes in plaster, mortar, or concrete. About 0.23 million cu. m. of sand conforming to fine aggregate Zone II of B. S. S. 882 and 1201 of 1954, required by the Durgapur Steel Project for constructional purposes have been located by the G.S.I. in the Kunur *nadi* and in Raturia (23°30′ : 87°17′), and Arjunpur-Angadpur (23°31′: 87°16′) areas within a radius of 19.3 km. around Durgapur (23°29′ : 87°18′). The sand should be washed to reduce the amount of silt from the sand (Roy, 1962).

Alluvial sand deposits are found below a thin cover of soil in many places in the Burdwan, Howrah, and 24 Parganas districts. Some of the sand referred to above for the Durgapur Steel Project are also found in the Raturia and Arjunpur-Angadpur areas. Such sand pits and quarries are found at Magra, Bally, Barrackpore, Dum Dum and at many places along the Grand Trunk Road between Calcutta and Burdwan. This type of sand deposits is widespread in the State, and also in North Bengal. These are mostly used for various constructional purposes. Calcutta and the surrounding industrial areas obtain sand for constructional purposes mostly from Magra and Pandua. The sand is yellowish, medium-grained, and does not contain much felspar, mica, and iron-bearing mineral.

Moulding sand is found on the northern bank of the Damodar river near Ondal (23°34′ : 87°11′), Durgapur and other places, and also near some rivers in the Raniganj coalfield. Magra sand from Baghmaidan, near Pandua, in the Hooghly district, as well as sands from Damra and Kotaidih 6.4 km. south-east of Asansol, is also used for this purpose (Brown and Dey, 1955, p. 436).

Glass-sands : These are rather rare. The purer and finer portions of the river sands may produce because of their iron contents only cheap variety of glasses, such as green bottle glass. Most of these glass sands are, therefore, obtained after crushing pure quartzite, pure firiable sandstones, and vein quartz.

There are good occurrences of fairly pure quartzite throughout the Archaean sedimentary rocks in Purulia, Bankura, Midnapur and Birbhum districts. Quartzites of the Iron-ore series occur as high ridges, in the southern part of the Purulia district near Bhandari (22°52′ ; 86°32′), as thin bands near Barabazar (23°02′: 86°22′), Layadih (23°10′ : 86°20′) and Jarangdih (23°10′ : 86°20′).

Fairly abundant occurrences of quartzites (and at places friable quartzite) in the Bankura district have also been recorded. Quartzites

which may be studied for their suitability for glass sands occur near Susunia (23°24′ : 87°00′), Kama (22°53′ : 86°44′), Kubasol (23°02′ : 86°01′), Bagjabra (23°02′ : 86°51′), Madhupur (23°02′ : 86°48′), Makrara (23°00′ : 86°51′), Diktor (23°03′ : 86°46′), Belkandi (23°02′ : 86°51′), Konra hill (23°23′ : 87°07′), and in the area between latitudes 22°51′ and 22°54′ and longitudes 86°45′ including Bamnipahar, Bhutadungri Balkadungri, Pirra, Hetiapathar, Rajakata, Karamara, Bithuala and Kharipara villages in the Bankura district (Hunday, 1950-52).

In the Midnapur district, a group of hills about 13 km. west of Sildah (22°35′ : 86°53′) is composed of hard grey and greyish white gritty quartzites, and large lenticular masses or irregular veins of vein quartz (Meddlicott and others, 1859, pp. 249-294). Bands of quartzites also occur near Dhangikushum (22°35′ : 86°35′) near the Singhbhum border.

In the Burdwan district, friable quartzites suitable for use as glass sands occur near the village Taldanga (23°46′ : 87°06′) about 2.4 km. E.S.E. of the Churulia railway station (Mehta, 1949 ; Brown and Dey, 1955, p. 429). The quartzite band is about 15.24 m. thick and continues for about 305 m. along the strike. The reserve appears to be moderately large. The quartzite is entirely free from felspar, but contains a small percentage of clay and streaks of sericite. A sample of sand obtained by crushing the quartzite gives on analysis SiO_2 70. 46%, Fe_2O_3 0·23%. It possibly contains a fairly high percentage of alumina in the form of clay, which can be reduced by washing. The total available reserve is about 7,112 tonnes (taking 14 cubic feet to a ton) down to a depth of three metres from the surface.

Most of the sandstones are not suitable for use as glass sands. But some of the friable sandstones are sufficiently pure and easy to crush so that they may be utilised for the purpose. Patches of such sandstones from the Barakar stage have been reported from near the Dabor colliery (23°47′ : 86°55′) and along the Nonia *Jhor* about 400 m. north-west of Itapore (23°47′ : 86°59′) in the Burdwan district. The patches of Barakar sandstones are in each case about 19 m. in length and 6.1 to 9.1 m. in width. The sandstones are rather rich in felspathic material and in mica. An analysis gives the following results : SiO_2 80.4 %, and Fe_2O_3 1.28 %. Moreover, the material is too coarse to be conveniently used directly in the glass industry. These sandstones may be used for the manufacture of inferior glass.

Sandstones in the Tangsuli basin near Suri, in the Birbhum

district, may also be examined for assessment in respect of suitability in utilisation in these industries.

Pure vein quartz is frequently used as glass sands. These may provide quartz almost completely free from impurities. The cost of crushing and sieving of vein quartz, as in the case of the quartzites may be heavy, but where a very high quality of glass, such as optical glass, is required the high cost is permissible. Occurrences of fairly good crystals of quartz are found in association with numerous pegmatites and quartz veins scattered in various parts of the Archaean tract in the western and northern districts of West Bengal.

Cherty quartzites suitable for silica bricks : A number of cherty quartzites and quartz veins are reported from the Bankura district which are likely to be suitable for manufacturing silica bricks. Some of these occur north of Kharkari (22°57′ : 86°59′), north-east of Jharia (22°56′ : 86°54′), south of Kankradara (22°56′ : 86°53′), south-west of Jambani (22°49′ : 86°54′), north of Asurgeria Uttar (22°50′00″ : 86°54′30″) and south-east of Sabubad (22°57′ : 86°50′), Gopalpur (23°07′ : 86°45′), Sagenbedya (23°05′ : 86°44′), Chilema (23°11′ : 86°59′), Amjhuri (23°48′ : 86°48′), Baidyanathpur (23°02′ : 87°56′), Banbedzya (23°05′ : 86°57′), Bansol (23°07′ : 86°46′), Handifila (23°08′ : 87°00′) and along the border of Bankura and Purulia districts.

Quartz and Felspar

Purulia District

Numerous quartz veins and pegmatites containing quartz and felspar are found in the Archaean terrain of the Purulia district. Several quartz veins within mica-schists are found near Dhadka and Rajauli (22°46′ : 86°35′) and Manbazar (25°03′ : 86°40′). Quartz veins occur abundantly between Kushgora (23°26′ : 86°34′) and Ghutlia (23°24′ : 86°37′). Large bands of cherty quartz occur on the ridges between Benagaria (23°07′ : 86°43′) and Chhotasagen (23°06′ : 86°44′), and near Nipenya (23°05′ : 86°37′) and Kashipur (23°26′ : 86°40′). Such materials are suitable for the manufacture of silica bricks. Brecciated quartz suitable for use in silica bricks occur in bands extending from Hatnadih (23°00′ : 86°30′) to Laspada (23°02′ : 86°25′), from Sargo (23°03′ : 86°24′) to Bardaha (23°03′ : 86°26′) and near Fatehapur (23°03′ : 86°30′). Quartz is also obtainable from pegmatites containing mostly potash felspar, quartz and mica. The occurrences or such mica-bearing pegmatites are mentioned in the Chapter (No. XVI) on 'Mica'. Besides these, mica-bearing pegmatites containing

quartz and potash felspar occur near Urma (23°09′ : 86°18′), Kantadih (23°12′ : 86°19′), Tamna (23°18′ : 86°23′), east of Barabazar (23°02′ : 86°22′), and north of Jambad (23°13′ : 86°35′) (Roy, 1962).

BURDWAN DISTRICT

K. D. Sukla (Krishnan 1953, p. 71) reported a few workable pegmatites in the Rupnarayanpur (23°40′ : 86°54′) area. Some promising pegmatites are seen near Daskiari (23°57′ : 86°55′), Ranidih (23°47′ : 86°30′), Barabani (23°45′ : 87°01′), Dhanudih (23°48′ : 86°51′), Gamarkai (23°48′ : 86°49′) and Sarkuri (23°48′ ; 86°49′). The reserves of quartz and felspars have been estimated to be fairly large (Krishnan, 1953, p. 71). Large quantities of Tertiary quartz pebbles and gravels are found near Kamalpur and Durgapur in the Burdwan district also described in the Chapter (No. VIII) on 'Building Materials.' These pebbles and gravels are at present extensively quarried. Iron coated quartz pebbles are also found associated with the lateritic deposits in the district.

BANKURA DISTRICT

In the Bankura district, a number of white quartz veins has been recorded near Sabubad (22°57′ : 86°55′), Teshpahari (22°53′ : 86°49′), Budhikila (22°53′ : 86°47′), Dhagara (22°59′ : 86° 47′), Rajakata (22°52′ ; 86° 48′), Sanardanga (22°52′ : 86°52′), Pirra, Bagjobra and Samarpacha (22°45′ : 86°51′), Pora Pahar (22°57′ : 86°49′), Sarenga-phulbaria (23°11′ : 86°53′), Chakaltasaer (23°06′ : 86°54′), Rangamati (23°03′ : 86°46′), Kubasol (23°02′ : 86°51′), Chandkhuritoli (23°03′ : 87°03′), Guniada (23°09′ . 86°45′), Tentulia hillocks (23°07′ : 86°50′), Padulara (23°08′ : 86°47′), Hasumdanga (23°05′ : 86° 50′), Gopalpur (23°07′ : 86°45′), and quartz boulders having rosy tint at Ampahari (23°27′ : 86°55′). The occurrences of quartz veins are so numerous in the Archaean tract of the district that only a few of them can be described here. Quartz in quartz-tourmaline veins are also available in many parts of the district. The fairly numerous cherty quartzite occurrences found in the district have already been incorporated under "Silica and Sand" of this chapter.

Hunday (1951-53) has enumerated several pegmatite occurrences in the Bankura district. These pegmatites contain pink felspars, white quartz, and mica with occasional tourmaline. These are described in Chapter XVI on Mica. Besides these pegmatites containing mainly quartz and felspars also occur near Jhantipahari (23°22′ : 86°54′), Bagakhulia (22°57′ : 86°57′), Khayerbani (22°58′ : 86°58′),

Rehgurbandh (22°57′ : 86°58′), Kadamara (22°57′ : 86°57′), Malidanga (22°48′ : 86°56′), Panrari (22°49′ : 86°56′), Gobindapur (22°50′ : 86°56′), Parashidanga (22°57′ : 86°59′), Bhaladiha (23°00′ : 86°57′), Kharkari (22°57′ : 87°00′), Tiring (22°58′ : 86°57′), Arbari (23°05′ : 86°59′), Botkula (23°05′ : 86°05′), Dhobagara (23°09′ : 86°57′), Goaldanga (23°07′ : 86°55′), Jamardihi (23°14′ : 88°00′), Mankhuri (23°09′ : 86°59′), Nischintapur (23°04′ : 86°55′), Ramchandrapur (23°05′ : 86°57′) and Tentulchita (23°07′ : 86°56′). These quartz and felspar deposits may be suitable for use in the ceramic industry. The quartz may also be used for the high silica refractory bricks.

Tertiary quartz gravels and pebbles are also found in the district, near Bishnupur, Danduria (23°00′ : 87°09′), Mukundapur (23°14′ : 87°10′), Jhari (22°49′ : 86°51′), Banskanali (22°58′ : 87°01′), and Madanmohanpur (23°09′ : 87°09′).

Iron-coated quartz associated with the laterites is also found in the lateritic area of the district.

Quartz crystal : Transparent quartz crystals within quartz veins and pegmatites are found 1.2 km north-west of Mujrakundi village (23°18′ : 87°01′), and about 400 m. east of Balidumdumi (23°18′ : 87°00′) village in the Bankura district.

Midnapur District

Quartz veins have been noticed within mica-schist and phyllite occurring south of the Kuilapal granite near the tri-junction of the Midnapur, Bankura and Purulia districts. Pegmatites containing quartz and felspars are round near Shiarbinda (22°45′ : 86°40′), Chakadoha (22°46′ : 86°39′), and Dhiukia (22°47′ : 86°37′). Quartz-tourmaline veins are also found near Kendapara (22°37′ : 86°44′) and in the adjoining places. Quartz veins are abundant and widespread in the Archaean terrain.

Vast quantities of quartz pebbles and gravels are available from the Tertiary gravel beds of the district. These occur near Jhargram, Kharagpur and Midnapur. The Jhargram-Gidni belt is extensively worked and the material is widely used in the State. It was used in the concrete aggregate for the foundations of the Howrah bridge. Some of these gravels might as well be suitable for shrouding in tubewells. Iron-coated quartz pebbles associated with the laterites are also widespread in the extensive lateritic parts of the district.

Quartz veins, pegmatites, quartz gravels and pebbles are also found in the Archaean and Tertiary terrain of the Birbhum, Darjeeling and Jalpaiguri districts.

Industries

Silica in the form of sand, quartz, quartzite, sandstone and quartz gravel is the major raw material for the manufacture of different types of glasses, and also for use in the ceramic and refractory industries. Sand is extensively used for sand-stowing in the collieries and for different constructional purposes. The ground substance is used in manufacturing sand-papers, grinding wheels, different types of cosmetics, soaps, paints, plasters, etc.

For the manufacture of glass, the sand should contain not less than 98.5 per cent. SiO_2 and iron-oxides (Fe_2O_3) should not exceed 0.05 per cent. and 0.008 per cent. in case of optical glass.

Prominent among the new and developing industries in India is the glass and ceramic industry. Currently, the annual production of glassware and chinaware in India is valued at Rs. 35 millions and Rs. 13 millions respectively. The production has also increased by 18 per cent. during 1958 due to an increase in the manufacture of sheet glass, vacuum flask, glassware, bottleware, and other ceramic products including porcelain, chinaware, insulators, crockeries, etc.

It is estimated that about 30 per cent. of the glass and ceramic factories of the country are located in West Bengal which contribute about 32 per cent. of the total output of glass and ceramic products. The raw materials are, however, imported from other States. The possibility of developing the internal resources, need proper attention.

The glass and ceramic industry is growing very rapidly in West Bengal. The Hindusthan Pilkington Glass Factory is located near Asansol, and the new site for the manufacture of optical glass in India has been selected in this area. A few old, well established and reputed firms, like the Sigcol Glass, and the Bengal Potteries are situated in Calcutta. The other raw materials required for the glass industry are soda, limestone and manganese. Of these, limestone and manganese of required specifications may be obtained from within the State.

Sand commonly used in foundry can be divided into three groups : (i) high silica sands, (ii) bank sand including dune sand, and (iii) natural moulding sand. Of these, the high silica sand is of great significance to the steel foundries. All these types of sands are available within the State. Most of the foundries situated in and around Calcutta, and those at Durgapur, Burnpur and Kulti fulfill their requirement of moulding sand mostly within the State.

Silica bricks, an important refractory, is described as the 'work-horse' of open-hearth furnaces ; the rapid growth of the Steel Industry

in the State has necessitated the increased use of silica bricks. These are extensively used in the construction of the main roof of the furnace, and in lining coke ovens and gas plants.

Production of Quartz-and Silica, 1957-1961
(in tonnes)

West Bengal	1957	1958	1959	1960	1961
	—	—	93	392	37
			(Purulia dist.)	(Purulia dist.)	(Purulia dist.)
			Value	Value	Value
			(Rs. 1,000)	(Rs. 2,000)	(Not known)

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CHAPTER XXIII

TALC/STEATITE

In composition, *Talc* is a hydrated silicate of magnesium and theoretically contains 63.5 per cent. SiO_2, 31.7 per cent. MgO and 4.8 per cent. H_2O, corresponding to the formula $H_2Mg_3(SiO_3)_4$. The hardness is 1—1.5 (Moh's scale) and specific gravity 2.7—2.8.

Steatite designates massive talc-rich materials, and pure type of industrial talc suitable for the manufacture of high frequency electrical insulators should not contain more than 1.5% CaO, 1.5% FeO, and combind Fe_2O_3 and Al_2O_3 4%.

Pyrophyllite is a hydrated silicate of aluminium and resembles talc in many of its properties.

Utensils and images used to be carved out of this soft talcose materials in many parts of West Bengal since a very long time. These stones are also known as 'potstones'. Cooking utensils of potstones are still used by religious minded Hindus.

The pure, soft mineral in trade is called talc, the well-known ingredient of talcum powder, but it also includes steatite, a massive compact variety.

Specifications

Paint Industry :—The tests specified by individual firms using talc in paint manufacture, either as a pigment or as an extender, vary considerably and may take into account (1) chemical composition, (2) the amount of acid soluble matter, (3) colour or brightness, (4) pH value, (5) apparent bulk density, (6) particle shape, (7) properties of oil absorption and (8) bulkage value. The presence of minerals which do not grind to a good white colour and of sulphates, such as gypsum, are generally regarded as objectionable.

The A.S.T.M. specification D-605—42 for magnesium silicate pigments (such as asbestine and talc) requires the product to have been produced by grinding a natural magnesium silicate obtained by underground mining, and stipulates that its chemical composition shall be within the following limits : SiO_2, 40—56 per cent. ; MgO, 20—32 per cent., loss on ignition 4—7 per cent. and moisture and other volatile matter not exceeding one per cent. Not more than two per cent. of the matcrial may fail to pass a 425 mesh scrcen.

High grade foliated talc which is used as an extender should have a low specific gravity and be of a good colour.

The British Standard Specification B.S. 1795 : 1952 for asbestine (trade name) for use in paint requires the product to consist of natural hydrated magnesium silicate, which may have been previously bleached. The coarse particles retained on a 240 mesh sieve must not exceed 0.5 per cent. ; water soluble matter 0.5 per cent. ; the loss in weight due to volatile matter at 98°—120°C must not exceed 0.75 per cent. The acidity or alkalinity of the water-soluble extract must not exceed 0.1 per cent. calculated as H_2SO_4 of Na_2CO_3 on the material. The normal oil absorption of asbestine should range between 20 and 35.

Rubber manufacture :—All the material should pass a 100 mesh sieve, and the residue on 200 mesh should not exceed 0.1 per cent.

Ceramics :—Those having a high lime and low iron content are stated to have a narrow firing range, whilst high alumina talcs have a lower maturing temperature.

Talc for use in radio-ceramic insulators should not as a rule contain more than one per cent. each of iron oxide and lime, and alumina should not exceed four per cent.

Talc, employed in the manufacture of electrical porcelain, contains about 30% MgO, with a maximum loss on ignition at five per cent. and should contain a total of not more than five per cent. lime, iron oxide, alumina and alkalies combined.

Paper manufacture :—Talc for this purpose should have a low content of calcium carbonate, be free from mica and iron oxide (limit one to two per cent.), but off-colour material is used for roofing papers.

Textile manufacture :—Talc should be of good colour and free from hard gritty impurities, such as quartz and calcite and should have a smooth greasy feel with less than one half per cent. moisture. Inferior grades are used in backfilling textiles.

Cosmetic :—The material should have a good white colour and a good slip. The material should correspond to Indian Standard's Specification IS : 1462—1959.

Aircraft material :—The specification No. D.T.D. 527 issued by the Government of the United Kingdom for fresh chalk (ground talc) should have MgO not less than 25 or over 35 per cent. SiO_2 not less than 40 or over 75 per cent. ; and loss on ignition at 900°C not over 20 per cent. The coarse particles remaining on a 200 mesh sieve must not exceed one per cent.

The U.S. National Stockpile Specification P-53 requires steatite block,

suitable for the fabrication of electrical insulators by cutting and machining to be supplied in definite grades as follows :—

(a) consisting of lumps weighing 900 gm. or over.
(b) lumps over 450 gm. but under 900 gm.
(c) lumps ranging between 225 gm. and 450 gm.

Consignments must consist of not less than one-third grade (a) and not over one-third grade (c).

According to specification M 239 of the U. S. War Production Board, talc for use in the manufacture of 'Steatite lava bodies' should contain the maximum of 1.5 per cent. CaO and 4 per cent. Al_2O_3.

The representative chemical composition of good quality commercial Indian steatite suitable for use in the production of lava bodies is as follows :—

Silica, SiO_2	61.24%
Ferric oxide, Fe_2O_3	0.02%
Alumina, Al_2O_3	1.42%
Lime, CaO	Nil
Magnesia, MgO	32.42%
Soda, Na_2O	Nil
Potash, K_2O	Nil
Loss on ignition, H_2O	4.90%

Uses

Talc has manifold uses in industry. Besides carved ornaments and images, dishes and cooking pots, the purer forms of soapstone and talc-schists are finding several applications in the modern industries because of their softness, flaky character and stability. Most of the talc is marketed as ground talc.

Talc is used in paints, ceramics, roofing, paper, rubber, toilet articles, and foundry facings. In paint, talc ('asbestine') acts as an extender.

In the ceramic industry, ground talc is used for wall tile, electrical porcelain and dinnerware.

Insulators made of steatite are having an added importance in the electrical industry.

Slabs of steatite are cut into switch boards, panels, table-tops, tanks and used in parts of radio sets, spark plugs and in other highly electrical insulators.

Calcined talc or 'lava', formerly used for gas tips, is harder than steel and is made into blocks that can be intricately tooled and threaded for use in electrical insulators and in refractories.

Steatite bricks are used in the furnaces where the slags are highly alkaline, as in the kraft paper mills.

Only the finest grades are used in toilet powders, lotions and face creams. These are also used as polishing agent, lubricant, wall plaster (particularly for acoustic purposes), filler, absorbent and dusting material (French chalk), and in acid-proof wares, mantles, fireless cookers and in crayons.

Occurrences

The steatite deposits in the western part of the State appear to have been formed by the alteration of the Dalma lavas, ultrabasic igneous rocks and chloritic schists and phyllites of the Iron Ore series.

Purulia District

Ball (1881) has given as many as 17 villages having potstone quarries between Maysara (23°04′ : 86°00′) in the Singhbhum district of Bihar and Khusbani (22°48′ : 86°34′) in the southern portion of the Purulia district in West Bengal. These were quarried since 1881, and the quality was also reported to be good. It is reported that cups were manufactured from potstones at Narsinghpur (22°45′ : 86°30′) near the Bihar border. Persistent band of talc-schists occur near Haludbani (22°56′ : 86°28′), Bara Kadam (22°54′ : 86°35′) and Andhaljhor (22°51′ : 86°40′). A large deposit of this material is reported to occur at Pukhurkata (22°52′ : 86°38′).

Bankura District

The numerous occurrences of talc-chlorite-tremolite rocks, occur as a narrow but persistent east-west belt of tremolite in the area south of Rudra (22°53′ : 86°44′) and extending beyond Longitude 86°45′ and tough and compact steatite near Matgoda (22°47′ : 86°55′), Manla (22°45′ : 86°46′), Chapadal (22°43′ : 86°54′) and Bhagu (22°54′ : 86°56′). It has also been reported that the utilisation of talc-chlorite-tremolite schists for carving pots, bowls, plates and other domestic utensils occur at following localities:—near Ghoratupa (22°43′ : 86°55′), Kuldiha (22°47′ : 86°54′), Maula (22°50′ : 80°46′), Panchpathar (22°56′ : 86°57′) and Matgoda (22°46′ : 86°55′). These support small-scale cottage industry in the area.

Midnapur District

Talc-schist, chlorite-schist, and 'lava'-schists occur at the northern flank of Lankaisini *Pahar* (.1621 ; 22°42′ : 86°35′), at Chandmari *Pahar*

(.1107 ; 22°40′ : 86°38′), in the 6.4 km. long belt between Amrola (22°40′ : 86°40′) and Patpinria *Pahar* (22°39′ : 86°44′), at Dhangikusum (22°38′ : 86°39′) and Tulaibani (22°38′ : 86°42′) in the north-western part of Midnapur district.

A. K. Dey (1937, p. 235) has reported that the deposits of soapstone near Khatkhura (22°35′ : 86°44′) found in association with the rocks of the Dalma suite are worked for manufacturing household utensils, and those near Kariaraba (22°46′ : 86°37′) and Dhenkia (22°47′ : 86°37′) were exploited until recently. He has also reported quarries of soapstone Gohalberia (22°39′ : 86°43′) (Dey and Fermor, 1934, 35 p. 38) and Katuchua (22°37′ : 86°41′).

Blanford (1859) observed that the chloritie and serpentinous beds occurring among the gneissose rocks in the southern part of Midnapur district were largely used as potstones, or in fine carving in the temples.

Darjeeling District

Small pockets of greenish and white talc have been locally developed in the Nezi block, Karmi Estate in the Pulbazar P. S. of the Darjeeling district near the Sikkim border. These have been formed by the alteration of chlorite-and talc-chlorite schists of the Daling series. These are interbeded with the schists, phyllites and quartzites of the Daling series, having a general strike W.N.W.-E.S.E. dipping at 30° to 70° S.S.W. They occur on the hill slopes ranging from 533 to 640 in altitude and are located within 1.6 km. north of Gok Bazar (27°06′ : 88°14′). The pockets are exposed in the Ramsuk and Tiruk Kholas, and are being worked since 1952. The materials vary in quality and grade from impure greenish variety to white massive talc (some approaching steatite grade). A. Hunday (Krishnan, 1958) besides examining three working quarries in the Ramsuk *khola*, found several pockets of talc over a wide area adjacent to these. The analytical results of five representative samples (Collected by Hunday) are given below:—

	1	2	3	4	5
SiO_2	52.16	56.62	57.76	57.50	54.96
Al_2O_3	8.79	6.29	1.11	2.40	8.25
Fe_2O_3	4.21	1.49	1.99	4.60	4.75
CaO	1.26	Nil	Nil	Nil	Nil
MgO	21.86	29.70	26.78	29.76	25.35
$-H_2O$	—	—	—	0.32	0.28
$+H_2O$	—	—	—	1.88	3.16
Loss	6.57	6.04	5.83	3.34	3.08
Total :	94.85	100.14	93.47	99.86	99.83
Rest	Alkali		Alkali		

The results of the analyses show that all the samples are of talc grade, excepting the second one which approaches the composition of steatite. The first three samples are from the 1st, 2nd and 3rd quarry in the Ramsuk Khola section, the 4th one is from a talc pocket in the talc-chlorite schist about 800 m. north-west of Chorten (.2953 ; 27°07′ : 88°14′), and the 5th sample is from a small pocket of talc near the confluence of a small tributary with Tiruk Khola about 1.6 km. north of Gok.

Firing (1,350°C) tests of these samples, carried out in the Glass and Ceramic Research Institute, Calcutta, are stated below :

Sample No.	*Vitrification*	*Fire Colour*
1.	Fused	Chocolate.
2.	Vitrified and shattered into pieces.	Deep brown on the surface and deep grey in the interior.
3.	Fused	Mixed brown and green.
4.	Almost vitrified	Dull white.
5.	Vitrified	Greenish grey.

The firing tests indicate that the samples are not suitable for use in better class ceramic products. However, sample No. 2 may be suitable for low grade ceramic wares. An addition of some alumina in the form of white clay may improve the colour of the fired products. Talc from these quarries may also be used in other industries, like roofing and in textile.

Hunday (1958) has calculated an approximate reserve of about 477 tonnes in the three quarries but the total reserve of this material in the area is likely to be more.

Jalpaiguri district : Occurrences of steatite are also reported from the Buxa beds at the debouchure of the Torsa across the Bhutan border.

The occurrence of talc-sericite schists has been recorded from the base of the Buxa stage at Lepachako near Buxa (26° 46′: 89° 36′). It has a variegated but prominent pink or bluish green colour. The material has been used successfully for lining of kilns in lieu of fire bricks.

Future prospects

Although the talc steatite deposits in West Bengal are not so extensive as compared to those found in Bihar, Rajasthan and Andhra

Pradesh, the fairly large deposits in the Purulia, Bankura, Midnapur districts and also some of the deposits in the Darjeeling district, certainly deserve a thorough investigation at an early date for assessment of their possible varied utilisation in many a growing industries in the State, including ceramic, refractories, paint and textile etc.

An investment of Rs. 300,000 for mining and development of soapstone deposits towards an anticipated increase in annual production, to the tune of six thousand tonnes by 1970-71 has been suggested by the National Council of Applied Research.

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CHAPTER XXIV

TUNGSTEN ORES

Wolfram ($FeMnWO_4$) and Scheelite ($CaWO_4$) are the principal ores of tungsten, although ten other tungsten-bearing minerals are also known. Wolframite is composed of two minerals, Ferberite ($FewO_4$) with 70 per cent. tungsten Oxide and Hubnerite ($MnWO_4$) containing 76·6 per cent. of tungsten oxide. Admixed in all proportions of the two ores of wolfram and scheelite, the eater contains a higher proportion (80 per cent.) of tungsten oxide than the former. Tungsten-ores are considered to be strategic minerals, long in demand for defence production. Though, the occurrence of wolfram and scheelite together in a deposit are fairly common, singular occurrence of either of the minerals forming economic deposits are also known. These deposits occur invariably in association or in close proximity *with granite rocks.*

Uses

The principal use of tungsten is in the manufacture of ferro-tungsten special alloys, such as high speed cutting steels, stellite, and tungsten carbide and tungsten powder. Besides these, other varied uses include the manufacture of tungsten filament for electric lamp and radio tubes in pigment industry, in the textile for the manufacture of fire-proof cloth and other fabrics through the use of sodium-para-tungstenite as washing agents, as mordents in calico-painting and in ceramic and glass industry for producing a yellow tint, for decolourising acetic acid etc., armour plates, gloves and projectiles.

Production of tungsten carbide drill bits has been recently undertaken in the Indian Bureau of Mines to meet its internal consumption and concurrent saving of imports.

Occurrence

In West Bengal, there are two known occurrences of tungsten-ores (wolframite and scheelite), both located in the south-western parts of the Bankura district. Of these, the occurrence around Chhendapathar village (22°45' : 86°45') near the border of Bankura and Midnapur districts was known since early thirties and worked intermittently during forties and fifties and continued during 1959-62 while the one found recently (Hunday, 1954) occurs in the hill known as Pora *Pahar* (22°57′ 30″ : 80°49′ 00″), is about 22 km. north of the Chhendapathar.

deposit. All the wolfram produced in India during the years 1959 to 1962, came from the Chhendapathar deposit in the Bankura district of West Bengal and there has been no report of production for the other known occurrence of deposit as at Deghana in the Jodhpur district of Rajasthan.

(1) *Chhendapathar (22°45′ : 86°45′)* : The deposit is 56 km. from Jhargram and 40 km. from Gidhni railway stations on the South Eastern Railway and is connected by a motorable road. It was first examined by Messrs. Tata and Sons nearly 30 years ago, but was never worked out due to wolfram content being low. The Geological Survey of India worked out the deposits during the war time in 1941-44, by quarrying the richer portions of the loads and collecting from alluvial deposits flanking the veins and reefs. A total quantity of 47 tonnes of ore were produced during that period from Puranapani, Parasia, Dudhianala, Satnala, Khariajhor and the flanks of the Thanpahari hill. After an interval of about six years, the Gauripur Industries Ltd. worked it for three years producing about seven tonnes of wolfram mostly from the float ores from depths not exceeding 2.4 m. from the surface.

The wolfram occurs in quartz veins and reefs which traverse the country rocks, Archaean phyllites and quartzites forming low hills and ridges. The wolfram-bearing veins are 1.22 to 1.83 m. thick and dip at angles of 30° to 60°. The mineralisation is sporadic, but extends for about eight kilometers in length including important occurrences at Thanpahar and Cheradungri near Chhendapathar. Although pieces of ore weighing upto 27 kg. and knots of it weighing upto 9 to 13.6 kg. have been occasionally found, the average wolfram content of the veins and reefs varies from 0.01 to 0.04 per cent. Some of the picked up samples from Chhendapathar gives on analysis, 73.10 and 72.90 per cent. of WO_3 (Krishnan, 1953). The associated minerals are molybdeuite, bismuthinite, ilmenite, pyrite, arsenopyrite, pyrrhotite, chalcopyrite and cassiterite. Some new occurrences of wolfram within 1.6 km. west of Chhendapathar have been located by S. K. Ramaswamy and S. N. P. Srivastava of the Geological Survey of India during 1951.

(2) *Pora Pahar* (22°57′ : 86°49′) : Hunday (Krishnan, 1954, p. 127) discovered a quartz-wolfram-scheelite lode at about 180 m. N. N. W. of Pora Pahar (778 m.) situated on the boundary fault running for about 160 km. along the southern margin of the granite gneiss.

Wolfram is in fairly rich association with scheelite and occurs here as disseminated grains and patches in two quartz veins striking N.N.E.-S.S.W. in sericite-quartzite. The larger vein ranges from 2.5 to 5 cm. in width and runs for about 3.5 m., and the smaller one occurring in close proximity of the first one is about 1.3 cm. wide and 5 cm. long with only a few small grains of wolfram.

Hunday (Krishnan, 1954) suggests that although this second occurrence near Pora Pahar may appear to be small and uneconomic should deserve immediate attention for intensive prospecting along prominent fault zones. This fault zone is conspicuous by its extension of over eleven kilometres in sheet 7/13 alone and also by a fair amount of width with prominently marked schorl gneiss (forming hills at places) and secondary iron-ores, cherty quartzites etc. In the intervening country between the Pora Pahar and Chhendapathar occurrence, there are at places occurrences of secondary iron-ores associated with quartz. Since tungsten-ores are easily susceptible to alteration with the formation of secondary iron-ore, it is necessary to ascertain through systematic prospecting the origin of those secondary ores and presence of any further deposits of tungsten in these areas where quartz veins are profusely seen.

Production

West Bengal is the only State in India that produced tungsten-ores during 1959 to 1962. The production figures as obtained from the Indian Bureau of Mines publications and reports are given below :

Year	1959	1960	1961	1962
Quantity in Kilograms	1,400	3,016	9,181	10,441
Value in Rupees	9,000	18,000	35,000	30,000

Wolfram produced contained 65% of WO_3 and average pit month WO_3 5.97 per Kg.

Prospects

Tungsten-ores, being known to be of great strategic importance apart from its utilisation in many engineering industries utilising high speed steel, deserves highest attention in respect of locating new deposits and also developing the known occurrences. The State

of West Bengal which has two known occurrences and one of which claimed to be the only producing deposit during 1959-62 in India, should certainly encourage vigorous search and development activities. It is not unlikely that prospecting activities may help to locate new deposits particularly in the intervening terrain between the known occurrences.

Prospects of tin-ore (cassiterite etc.) deposits in this region, abounding with evidences of profuse pneumatolysis, should not be overlooked.

It is envisaged (by the National Council of Applied Research) that with the proposed investment of Rs. 600,000 during 1961-71 in this regard in the State, a production of 3,048 tonnes of tungsten-ores will be obtained.

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CHAPTER XXV

VERMICULITE

General

Vermiculite is a hydrated magnesium aluminium silicate of varying composition with a micaceous habit. It is a decomposition product of mica, but may also be formed by direct hydrothermal means or by a combination of the two. In chemical composition, vermiculite resembles biotite (phlogopite etc.) with the distinction that much alkalies have been removed and water has been added. It shows a characteristic exfoliation on being heated, unlike other micas. It is to the combined water (which varies from 4.3 to 14.8 per cent.), that vermiculite owes its exfoliation while its other constituents may vary over a wide range. Crude vermiculite may vary in colour from black to brown or yellow. The flakes are flexible and non-elastic with generally a golden lustre. True vermiculite occurs in association with altered ultrabasic rocks. It has an apparent density of 810—1,458 kg. per cu. m. Vermiculite owes its commercial utility to its peculiar property of exfoliation from 12 to 25 times its initial volume when heated between 800 and 1100°C. On exfoliation, it changes to a golden bronze colour with an apparent density of 81-162 kg. per cu. m. Because of the extreme lightness of the exfoliated material, it has gained commercial importance for making light weight concrete.

Its main use is in the manufacture of heat and sound insulation materials. It is used for insulating refrigerators, furnaces, house insulation, insulation cement and other miscellaneous purposes. Patented bricks prepared of vermiculite and a suitable bonding material are sold in the market under such names as Thermo-flakes, pyrok, Zonolite, Exflor etc. A brick measuring 0.23 m. × 0.1 m. × 0.06 m. may weigh only 500 gms. An imported exfoliated vermiculite sample (-4 mesh) marketted under the trade name 'Unifil' (price about Rs. 50/- per tonne in 1956) for insulation purposes, has a bulk weight of about 4308 kg. per cu.m.

Vermiculite generally occurs as compact aggregates in lenticular and irregularly shaped deposits (with wide variations of thickness at short distances) and in association with basic and ultrabasic rocks, mica-schists (intruded by pegmatite veins), pyroxene gneisses and granulites

Uses

In the manufacture of thermal insulating (fire-resisting and non-moisture) plasters fibrous gypsum, in the proportion of 80,000 cu. cm. of vermiculite to 50.8 kg. of gypsum and 75.12 mm. of exfoliated vermiculite is used.

Vermiculite concrete for roofing purposes usually has a density between 320 and 416 kg. per cu.m. It is used also in the manufacture of golden coloured plaster used in theatres, film and broadcasting studios, which is made of a mixture of portland cement, a lime plasticizer, vermiculite and water.

Vermiculite is also used in lubricants, paints, filler, plastics, wall paper manufacture etc. Unexfoliated vermiculite is used in drill rods, and in the annealing of steel.

There is a growing utilisation of vermiculite plasters for the protection of structural steel works in U. S. A. and U. K. These plasters when applied in thin coats considerably increase the fire resisting properties of structural materials.

Localities

A few new occurrences of vermiculite, biotite and its alteration products have been found by A. Hunday during his investigation in the Bankura district in West Bengal. Some of these occurrences were further investigated by M. S. Balsundaram later (Roy, 1962).

(1) *Datkigora* (22°58′ : 86°57′) : Occurrences of bronze coloured mica books are noted about 200 m. east of Datkigora village. Datkigora is 10 km. east of Khatra (22°58′ : 86°51′), and the nearest railway station is Bankura about 56 km. away.

The material near the surface is stained, weathered and generally reddish in colour. They also exhibit buckling and assume a greenish tinge at depth. The deposit is 24.4 m. long (along E.N.E-W.S.W.) and 15.24 m. wide, but Balsundaram (Ray, 1962) got indications of the material 29 m. apart. Pitting and trenching proved the existence of it an area of about 465 sq. m.

The country rocks include calc-silicate rock, granite gneiss, pegmatite and quartz veins striking N.N.E.-S.S.W. with steep dip. The vermiculite is found in paddy and is not mixed with any other material. The staining is less at depth. It occurs close to the surface on the northern side.

Balsundaram (Ray, 1962) calculated a reserve of 1524 tonnes in an area of 465 sq. m. upto a depth of 1.5 m. assuming 0.446 cu. m. of the material as weighing one tonne. He also found this deposit as an isolated one.

On testing, the material expanded to thrice it volume (maximum 3¾ and minimum 1¼) when heated between 900°C. and 950°C. Balsundaram thinks that this is not true vermiculite which should expand at least 8 to 12 times to be of commercial grade. He considers it to be hydro-mica (sp. gr. 2.31), an alteration product of biotite. The expanded material leaves a silvery brown residue which may find use in the paint industry.

This material was subjected to detailed testing and benefication processes at the National Metallurgical Laboratory, Jamshedpur and benefication processes at the National Metallurgical Laboratory, Jamshedpur and the results appear encouraging and are given below.

The sample of vermiculite (dark bronze to greenish yellow in colour) contained 78.5 per cent. vermiculite, and when exfoliated at 950° C. (-1.3 cm. or -½″ size), had a bulk weight of 212 kg. per cu. m. Best result is obtained when heated in a muffle furnace at 950° C. for 90 seconds. The sample contained minor amounts of fine gangue such as clay, quartz, amphibole and magnetite. It assayed (per cwt.)—

		Per cent.
SiO_2	...	36.01
Al_2O_3	...	17.06
Fe_2O_3	...	11.85
FeO	...	0.89
MnO	...	0.12
TiO_2	...	0.31
CaO	...	2.36
MgO	...	13.77
P_2O_5	...	0.10
Loss on ignition at 105°C	...	8.25
Loss on ignition at 95°C	...	16.88

Beneficiation tests were performed employing crushing, washing, wet screening and tabling. The sample of (-1.3 cm. or-½″) size was ground in a ball mill, and the mill discharge was wet screened into two fractions (-1.3 cm. or-½″) 20 mesh and -20 mesh. The -20 mesh fraction was tabled. The (-1.3 cm. or -½″) 20 mesh fractions and the table concen-

trates were exfoliated. The bulk densities of four mesh fractions of the table concentrates were found to be 131, 167, 168 and 241 kg. per cu. m. A vermiculite concentrate of 94.3 per cent. purity and with a recovery of 78.2 per cent. was obtained in the 20 mesh fraction. Although, the bulk weight of the exfoliated concentrates were slightly higher than those of imported products, the beneficiated materials could be regarded as satisfactory marketable grades of concentrates.

(2) *Niche Bhuenpur* (23°25′ : 87°05′) : Hunday and Gupta (West, 1950) reported an occurrence of a soft, bronze coloured mica in fairly big sized books often exceeding 10 sq. cm. in size, in pegmatite at Niche Bhuenpur. The mica swelled up a bit on heating, but it may not be true vermiculite. Data on detailed testing of this material are lacking.

Hunday (Krishnan, 1952, 53 ; West, 1950) reported the following occurrences of biotite, its alteration products and inferior vermiculite from the Bankura district.

(3) *Gourangdihi* (23°17′ : 87°01′) : Somewhat altered biotite of over 81 sq. cm. in size was found from a depth of about 2.4 m. in a small prospecting pit about 400 m. east of Gourangdihi village. The altered flakes show slight expansion on being heated over a Bunsen flame for a few minutes.

(4) *Karanjora* (23°22′ : 87°02′) : Biotite ranging in size from 6.8 to 13 sq. cm. is found 1.6 km. north-east of Karanjora.

(5) *Mankanali* (23°19′ : 87°02′) : Biotite flakes measuring 6.8 sq. cm. are found in the pegmatite exposures noted on the track from Kendbani to Mankanali.

(6) *Gualdang* (23°21′ : 87°06′) : Altered biotite books up to 61 sq. cm. in size are found in an abandoned prospecting pit (4.27 m. × 3.66 m. × 1.52 m.) 400 m. S. S. E. of Gualdang village. Some of the mica flakes show a certain amount of expansion on being heated over the Bunsen flame for a few minutes. The colour of the mica also changes from black to silvery white.

(7) *Pabayan* (23°22′ : 87°14′) : Bronze coloured soft mica books (vermiculite ?) ranging in size from 41 to 61 sq. cm. are found on the high contours about 400 km. north-west of Pabayan village. Some of these mica flakes show little expansion on being heated over a Bunsen flame.

(8) *Itadangra* (22°23′ : 87°04′) : Bronze coloured soft mica

books (vermiculite ?) are found near the contact zone of a pegmatite intrusion and hornblendic rock in the *nala* cutting S. S. W. of the Itandangra village. On being heated, the mica samples show exfoliation.

(9) *Kalipur* (23° 21′ : 86° 04′) : Bronze coloured soft mica books (vermiculite ?) have been found in a small pegmatite exposure. On being heated, these mica flakes show some amount of expansion.

Some of these altered biotite samples were tested by Messrs. Burn and Co., in their ceramic laboratories at Raniganj. According to them, these micas are inferior to the true South African vermiculites and are not suitable for use in insulating bricks etc. but in the disintegrated state these micas may be useful for plastering purposes in the paint industries.

Prospects

In the light of manifold uses of vermiculite as outlined above, the deposits already located in the State need utilisation in many industries, particularly in the paint and plaster industries etc., for the inferior grades and in insulating industries for the better grades after economic beneficiation.

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GROUP – 11 : OCCURRENCES OF MINERALS/ MATERIALS OF LITTLE OR YET UNKNOWN ECONOMIC IMPORTANCE.

CHAPTER XXVI

1. ANTIMONY

The principal ore of antimony is *stibnite* (Sb_2S_3) containing Sb-71.4 per cent. and S-8.6 per cent.

In the manufacture of anti-friction metal on alloying with lead, the antimony metal finds its principal use. Besides, it is also used by itself, as alloys or as antimony salts in many industries as storage batteries, ship nails, bearing metal, in application to the eye as *surma*, in safety matches, in veterinary surgery, pyrotechny, in military uses for producing dense white smokes, in signals, in painting, in vulcanizing rubber, in glass and porcelain industries, in medicine etc.

Only a minor occurrence of antimony-ore of academic interest is known in the State, associated with the galena deposits of the Dhadka area (22°48′ : 86°30′) in the Purulia district.

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2. APATITE AND PHOSPHATES

Apatite is primarily a phosphate of calcium containing also chlorine or flourine or both. Thus two compounds are known to be included in these species, *viz*, *Jluor-apatite* $3Ca_3P_20_8$ CaF_2, and *Chlor-apatite* $3Ca_3P_20_8$ $CaCl_2$,both containing 41 to 42 per cent. P_20_5.

Colour is usually sea green, although bluish green and violet blue varieties are also known. Hardness is 5, sometimes being 4.5, while the specific gravity is 3.17-3.23.

Apatite is richest in the phosphate content among all other natural and artificial sources of phosphate which include : (i) Phosphatic nodules (25 per cent. P_20_5), (ii) Monazite (26 to 28 per cent. P_20_5), (iii) Bore meals, (iv) Blast furnace slag containing recoverable phosphates ranging from 3.6 to usually 8 per cent. and sometimes 18 per cent. P_20_5 *(Basic Bessemer Process)*.

Uses : The phosphates from these various sources are principally used in the manufactures of fertilisers in the from of various super-phosphates, phosphoric acid, elemental phosphers etc. Other uses of phosphate products include in the manufacture of high phosphers pig iron pipes, ceramics, pharmaceuticals, fire proofings, decolouring and lining of leather in tanning industry, dental cements, textiles, soap making and purification of sugarcane juice.

For the manufacture of *superphosphate* (i) iron and aluminium content should not exceed 3 per cent. in the rock phosphate, (ii) P_2O_5 may range from 27.31 to 40.32 per cent., (iii) $CaCO_3$ between 2 and 4.5 per cent. is desired, (iv) high fluorine content is objectionable, but some firms recover flourine bearing gas, as a source of hydro-flouric acid, (v) the rock phosphate is suitably ground at the initial stage so that 80-95 per cent. pass through 100 mesh (B.S.S.).

Some firms use phosphate containing (a) 30.65 to 38.35 per cent. phosphoric acid (b) silicon 0.12 to 6.60 per cent. and (c) fluorine varying from 1.30 to 4.24 per cent.

Occurrences

There is hardly any known economic deposit of apatite in the State. However, certain occurrences are reported, which include the following : (i) Apatite is found associated with barytes at Malthol (23°26' : 86°26') in the Purulia district. (ii) The mica-peridotite and lamprophyre suite of intrusive rocks in the Raniganj (Banerjee,

1933) and Darjeeling coalfields contain apatite, and the calcium phosphate content of these rocks vary from 4.5 to 12.5 per cent. (iii) Even 11.5 per cent. of apatite was found in this type of rock (Holland and Saise, 1895). Holland (1894) recorded 11 per cent. P_2O_5 in some portion of lamprophyre dykes in the Giridih coalfield. (iv) The maximum length and breadth of apatite crystal found in these rocks in the Raniganj coalfield are 0.92 mm. and 0.083 mm. respectively (Banerjee, 1953). According to Dunn (1941) the grade is too low to be of any economic value. (v) Certain mica-bearing pegmatites contain apatite as an accessory mineral.

Further detailed investigation of the Archæan terrain of the States, particularly in the region of pegmatites, may prove worthwhile in the prospecting for apatite deposits.

Similarly, search for any possible deposits of rock phosphates (containing the collophanite, the hydrated Ca-phosphorite, Ca_3 Po_4 $2H_2O$) known as phosphorite which greatly resemble limestone, may be worthwhile particularly in the coastal regions, estuaries and old shore lines.

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ARSENIC

The principal ores of Arsenic are orpiment ($As_2 S_3$ with As 61 per cent.) realgar (As S with As. 70.1 per cent.) and arsenopyrite mis-pickel ($FeAs_3$ with As 46 per cent.) Besides, lollingite ($FeAs_2$) and leucopyrite ($Fe_3 As_4$) are also known.

The manifold uses of Arsenic compounds, are in the manufacture of insecticides and fungicides, medicines, metallurgy, paint industry, for the manufacture of antifoul paints, wood preservations, weed killers, in the preparation of arsenical copper, lac wares, and in the glass industry etc.

Occurrences

Certain occurrences of arsenical pyrite are reported from the following localities of the State :—

DARJEELINO DISTRICT

(i) *Samthar Hill* (26°58′ : 88°54′) :— Mallet (1875) describes an occurrence of arsenical pyrite on the northern flank of the Sampthar hill about 800 m. W.S.W. of the highest peak and about 2.4 km. north-east of the Yangti Mine, at a height of about 1,200 m. above m. s. l.

Arsenopyrites occur here in association with iron-pyrites and a little copper-pyrites with traces of lollingite in a metalliferous band, about 30 cm. thick and with two thirds of ore, within rusty looking, fine-grained quartzose schist.

Auden traced the mineralisation for a distance of about 6.5 m. There are two mineralised bands 15 to 23 cm. in thickness, separated by 25 cm. of quartz-schist in the thickest part of the lode. Chemical analysis shows that the ore is predominantly arsenopyrite, with traces of lollingite and a little chalcopyrite.

The mineralisation is along certain bands in the fine grained grantzose rock and along shear planes. S. K. Ray gives an analysis of the ore sample as :—

Arsenic content	7.50%
Copper	1.30%
Iron	20.79%
Sulphur	20.74%
Insoluble	49.11%
Total :	99.44%

(ii) *At Paunbu Khola* :—Marian Stefanski (1948) has reported an occurrence of arsenical copper-ore in the ravine of Paunbu *khola* about 800 m. north of Yetigari monastry south of peak 3, 621. According to him, the thickness of the vein varies within 15 cm. and the ore samples on assaying, give arsenic 11.8 per cent. and copper 3.68 per cent. Stefanski considers that the deposits would prove economic if the area is made accessible.

Further, detailed investigation of the occurrences are warranted in order to ascertain the commercial prospects of the deposits.

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BARYTES

Barytes ($BaSo_4$) has a mineral composition of BaO, 65.7 per cent. and So_3, 34.3 per cent.

Uses :—There are fairly numerous uses for barytes and Ba-compounds. The principal uses are, in the manufacture of lithophone (white paints), as a fillers, in rubber and textile industries, in the preparation of drilling muds in the from of $BaCl_2$, Ba $(NO_3)_2$, in tanning industries and in the preparation of photographic chemicals, insecticides etc.

The high specific gravity, inertness, low cost and purity particularly make it suitable for use in drilling oil wells. Precipitated $BaCO_3$ is also reported to be commonly used as rat poison.

Specification

Indian standard specification for barytes includes the following :—
For paints.

(i) The material should contain not less than 95 per cent. $BaSO_4$.
(ii) Carbonates not exceeding 0·5 per cent. (expressed as Carbon dioxide).
(iii) Material should be supplied as a dry powder.
(iv) When lead-free material is required, it should contain not more than 0·05 per cent. of lead or compounds of lead.
(v) The volatile matter should not exceed 0·5 per cent.
(vi) Residue on sieve (BSS 240 mesh) not more than 0.25 per cent.
(vii) Oil absorption should be between 6 & 12.
(viii) Colour, not inferior to the approved sample.
(ix) Water soluble matter should not be more than 0·5 per cent.

PURULIA DISTRICT

(1) *Malthol* (23°26′ ; 86°26′) : Barytes occurs in association with apatite, allanite, galena, bismuthinite and bismuthosphaerite near Malthol. It occurs in veins traversing granite in a 4·8 km. long and 200 m. wide zone. Some of the specimens are of excellent quality.

(2) *Belna and Raghudih* (23°26′ : 86°27′) : Veins of barytes extending over a length of 15.2 m. and associated with allanite have been recorded from Belna and Raghudih. The baryte content is said to be 50 to 60 per cent.

(3) *Balarampur* (22°59′ : 86°38′) : Barytes occur near the village Balarampur. The deposit extends from the Kumari *nala* to the hill south of the village.

(4) *Chas Road Railway Station* (23°25′ : 86°12′) : Baryte is also reported from the area 3.2 km. west of the Chas Road Railway Station, and about 19 km. north-west of Purulia.

Dunn (1941) and Khedkar (1950) recommended thorough investigation of these areas for barytes to ascertain its economic potentialities.

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5. BISMUTH ORES

Bismuth is used in medicines, cosmetic and in manufacture of alloys (with lead, tin, cadmium and other metals) which characteristically have low melting points and non-shrinking properties. Such alloys are used in making of safety fuses and plugs for electrical apparatus, moulding and pattern metals, mounting for dies, in the production of radar equipments and bismuth amalgam in dentistry, in pharmaceutical compounds etc.

Purulia District :—Two bismuth minerals, bismuthinite (Bi_2S_3 ; Bi-81·2, S-18·8) having hardness 2 and sp. gr. 6·4-6·5, and bismutosphaerite $Bi_2(CO_3)_3,2Bi_2O_3$ having hardness 3-3·5 and sp. gr. 7·3-7·4, have been recorded in association with barytes from Malthol. They occur in very small quantities and are of academic interest only.

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6. CORDIERITE

Cordierite is a silicate of magnesium and aluminium ($2MgO,2Al_2O_3, 5SiO_2$) with hardness 7 to 7.5 and sp. gr. 2.60 to 2.66.

'Iolite' is a gem variety of the mineral cordierite.

Burdwan district : Cordierite bearing vitrophyric and hornfelsic rocks associated with the burnt outcrop of Laikdih coal seam occur in the Ramnagar area of the Raniganj coalfield. They show a remarkable development of idioblastic cordierite. These crystals of cordierite occur in all odd shapes enclosing partly or completely the gangue matrix. These rocks have been produced as a result of the vitrification of the shales of the Barakar series by the intrusion of the mica-lamprophyres. This is of academic interest only.

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7. CORUNDUM

Corundum (Al_2O_3) is of great utility in abrasive industry in view of its hardness (H—9, sp. gr. 3.95 to 4.10).

The gem varieties of corundum are known as ruby and sapphire.

Specifications

In the manufacture of coated abrasives, I.S.S. specifications need that corundum should have 90 per cent. Al_2O_3, Hardness on Moh's scale (min). 9 and sp. gr. 3. 90.

For the manufacture of crucibles, fine grained corundum (—200 mesh) with 90 per cent. Al_2O_3 and iron oxide not exceeding three per cent. is blended with clay. The presence of felspar is undesirable.

Aluminium in sintered form (M. P. 2010°C) and known as sintered corundum is used in sparking plugs, muffles, pyrometer, refractory crucibles, special bricks and crucibles.

Artificial abrasives (emery powder, alundum, carborandum, norbide) which are manufactured from bauxite and coke, are also being increasingly used replacing natural corundum.

Purulia district :—

(1) *Salbani* (23° 04′ : 86° 17′) : Blue crystals of corundum upto 1·3 cm. in diameter occur in coarse kyanite veins 60 cm. to one metre thick, within mica-schists near Salbani in the Purulia district (Warth, 1896). The coarse quartz-kyanite veins containing corundum occur in a belt about 11 km. long.

(2) *Paharpur* (23° 23′ : 86° 47′) : Crystals of corundum varying in size from a fraction of a centimetre to about 2.6 cm. across, are found in the biotite-plagioclase gneiss near Paharpur in the Purulia district.

(3) *Bhagabandh Village* : (23° 11′ : 86° 44′) : Few columnar crystals of corundum are found associated with galena in epidote-bearing pink aplitic gneiss and pegmatite in a small tank about 800 m. east of the Bhagabandh village (Krishnan, 1954).

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8. GARNET

Garnets form a group of complex silicates of calcium, magnesium, iron and manganese with wide variation in the elements present. Some of the garnets contain also titanium and chromium. The general varieties include Grossularite $Ca_3Al_2\ (SiO_4)_3$, Pyrope $Mg_3Al_2\ (SiO_4)_3$ Almandine $Fe_3Al_2\ (SiO_4)_3$, Spessartite $Mn_3Al_2\ (SiO_4)_3$ Andradite $Ca_3Fe_2\ (SiO_4)_3$ and also $(Ca, Mg)_3$, $Fe_2\ (SiO_4)_3$, $Ca_3Fe_2\ [(SiTi)O_4]_3$, Uvarovite $Ca_3Cr_2\ (SiO_4)_3$, Schorlomite $Ca_3\ (FeTi)_2\ [(SiTi)O_4]_3$. In hardness, garnets range from 6.5 to 7.5 while in sp. gr. they range from 3.15 to 4.3.

Grossularite and almandine varieties are used as abrasives. In the abrasive industry, garnets are extensively used for giving finish to wood, leather, hard rubber, plastic, etc. Garnet coated abrasives occupy an intermediate position between the low cost quartz abrasives and high cost artificial abrasives.

Transparent varieties of garnet are valued as semi-precious stones. Cutting and polishing industry of garnet are located in Delhi and Jaipur.

Occurrences

Purulia district : Detrital garnet occurs in the garnetiferous mica-schist area of the district. Chandra (Krishnan, 1954-55) noted superficial occurrence of garnet crystals derived from mica-schist, from south

of *Manikdih* (23°09′ : 86°59′). It is hardly of any commercial importance due to its meagre distribution.

Bankura district : Hunday (Krishnan, 1954) has reported development of fairly big euhedral and sub-hedral crystals of garnet in the amphibolite and mica-schists—the following localities are of special mention :—

(1) *Dhanjar* (22°47′ : 86°46′) : In the *nala* section to the north of Dhanjar.

(2) *Jantadumur* (22°46′ : 86°50′) : In the Bhairabbanki *nadi* section to the south-east and east of Jantadumur.

(3) *Lapam* (22°45′ : 86°49′) : In the *nala* section to the east of Lapam.

(4) *Baradi hillock* (22°53′ : 86°56′) : In the Kasai river section to the north-west and south-west of the Baradi hillock (.383).

A. K. Roy (1943) recorded concentration of garnet in surface detritus at *Bagdubi* (22°46′ : 86°45′) and *Chhendapathar* (22°45′ : 86°45′).

Midnapur district : Garnet occurs both as a constituent of the country rock and also in concentrated state in surface detritus in the north-western part of the Midnapur district. Garnet sands occur along the stream which traverses the mica-schists south of Gidni (22°30′ : 86°31′) in the north-western part of the district. These garnet sands may be useful as abrasive (Dunn, 1941). Garnetiferous mica-schists are generally the source rock for garnet in this area and in the adjacent areas of the Bankura district.

Darjeeling and Jalpaiguri districts : Garnet occurs as a constituent of the garnetiferous schists and gneisses belonging to Daling and Darjeeling series. One garnet zone (of zonal metamorphism) about 800 m. wide is reported from the Gayabari railway station (26°52′ : 88°18′) to the Gayabari village (26°50′ : 88°13′), a distance of about 10 km. in E.N.E.—W.S.W. strike direction (Dey, 1956). The maximum size of garnet porphyroblasts recorded is two millimetres in diameter. The rocks of the garnet zone are the mica-schists with minor greywacke schists. Similar garnet zone is also found in the Kalimpong area.

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9. GEMSTONES

West Bengal has not been endowed with good deposits of gemstones. A brief description of a few occurrences mainly of semi-precious stones are given below :—

Agate, amethyst, etc. : Varieties of agate, chalcedony, amethyst and rock crystal have been found in the amygdaloidal basalt of the Rajmahal hills in the Birbhum and Murshidabad districts.

Apatite : Beautiful clear, green crystals of apatite, but rather too small for cutting as gem, have been found in a barytes vein near Malthol village (23°36′ : 86°26′) in the Purulia district.

Beryl : Greenish crystals of beryl may be found in the mica-bearing pegmatites of Bankura, Purulia, Midnapur and Birbhum districts.

Corundum : Crystals of blue corundum occur in kyanite veins near Salbani (23°04′ : 86°17′) in the Purulia district, but are not sufficiently clear to be classed as sapphire.

Garnets : Garnets occur along some of the streams traversing the mica-schist country in southern Purulia and western Midnapur and Bankura district. But hardly any gem varicty of garnet is reported in these deposits which are mostly suitable as abrasive. The garnets of the garnetiferous schists and gneisses of the Darjeeling district also are not promising for this purpose.

Jasper : Jasper may be occasionally found associated with the lavas and tuffs of the Iron-Ore series in the Purulia, Bankura and Midnapur districts.

Kyanite : None of the pale blue kyanite of the Purulia or Darjeeling districts is of sufficiently good colour to be used as a gemstone.

Rock crystal : Rock crystal is occasionally found in Rajmahal traps and in geodes, and also in the mica pegmatites. Transparent quartz crystals occur in the pcgmatite about 800 m. north-west of Mujrakundi (23°18′ : 87°01′) and about 400 m. east of Balidumdum (23°18′ : 87°00′) in the Bankura district. The crystals range from 7 to 7.6 mm. in length and 1.3 to 2 cm. in diameter (Hunday, 1950).

Tourmaline : Although tourmaline occurs very commonly in the mica-bearing pegmatitcs, but a gem variety is rare.

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10. GRAPHITE

Graphitic schists occur within the Archaeans. But these are too poor in quality and too finely and intimately mixed with the other constituents to be workable as a source of graphite. But some of these have been used as cheap paint materials.

Graphite has manifold uses which includes as a filler, in the manufacture of crucibles, retorts, muffles, refractory articles, electrode pastes and brushes ; lubricants for heavy and light bearings, pencil industry, paints, dry batteries, foundry factories, as moderators in the form of graphite bricks in atomic reactors.

Occurrences

Purulia District :—

(1) *Kalajhor* (23°26′ : 87°35′) : Graphite occurs as disseminated flakes in mica-schists, about 1.2 km. south of Kalajhor. Here a vein of graphite is reported to have been worked for several years.

(2) *Kashipur and Gaurangdih* : (23°26′ : 86°46′) : Local concentrations of fine flakes of graphite occur in felspathic mica-schists forming a belt in the area around Kashipur and Gaurangdih.

(3) *Bongora* (23°29′ : 86°32′) : A vein of graphite about one metre in thickness occurs in mica-schists near Bangora about 6.4 m. S.S.E. of Anara. S. Deb (1949) examined this deposit near Adra and found 60 per cent. graphitic carbon in the graphites.

(4) *Dimadiha* (23°29′ : 86°09′) : Graphite has also been recorded at Dimadiha near Bihar border.

(5) *Panchet Hill* (23°37′ : 86°45′) : B. C. Roy (1938) has reported small flakes of graphite in the biotite-schists and pegmatites in the Panchet Hill area. Trial pits were sunk, but the graphite flakes were generally minute at the surface and there was no evidence of an enrichment at depth to warrant deeper excavations.

In south Purulia, beds of carbon phyllite are associated with the Dalma lavas. In some phyllites the content of amorphous carbon is very high.

Bankura District : Traces of graphite flakes have been found by Hunday (1953) in the quartz-schist and quartz-sillimanite schists (khondalites) in the north-western parts of the Bankura district. Graphite-schists occur in *Bagdiha* (22°45′30″ : 86°45′00″), *Jani* (22°57′ : 86°44′) and *Panijia* (22°52′00″ : 86°45′30″) mouzas. Occurrences of carbon phyllites were also noted in the Kasai river section.

Occurrences of small exposures of carbon phyllitic/schists as noted by A. Hunday (1953) in the Bankura district (Sheet 73 I/13) are mentioned below :—

(i) On the high contour and along the low lying area south-west and south-east of 0·539 hillock about 1·2 km. north of *Dabar* (22°57′03″ : 86°45′30″) ;

(ii) To the north of a tank to the south of Mithium village (22°50′00″ : 86°45′30″) ;

(iii) In the Kasai river section about 1·6 km. north of *Sasunara* village (22°52′44″ : 86°56′30″), and west and south-west of *Baradi-Kalaputhar* village (22°52′30″ : 86°87′30″) ;

(iv) North of *Galla* village (22°52′30″ : 86°46′30″) ;

(v) In the *Murajhor* section north of *Dahala* (22°57′00″ : 86°56′30″).

Darjeeling and Jalpaiguri districts : Graphitic schists formed from the altered carbonaceous shales of the Damuda rocks, and graphitic lenses in the Daling (*e.g.* in the Rakti river) and Darjeeling series have been reported (Hunday, 1953).

In the Darjeeling district, occasional thin bands or lenses of carbonaceous matter (usually graphitic) developed in the kyanite zone of the Darjeeling gneiss between the stream at 1¼ milestone (west of Sukhiapokhri) and Tanglu on the Sukhiapokhri-Manikanju-Tanglu road.

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11. GYPSUM (SELENITE)

Gypsum occurs in crystalline (selenite), massive (alabaster) and fibrous (satinspar) forms. It has a composition of $CaSO_4$, $2H_2O$. When heated to 100°C, Plaster of Paris ($2CaSO_4$, H_2O) is formed and when heated to 200°—250° C, all water is removed.

USES :

Gypsum is used in ceramic and cement industries, fertilizers, for the manufacture of Plaster of Paris, in the manufacture of insecticides, for the manufacture of gypsum plate for petrological microscopes, crystalline varieties for ornamental and artistic uses, alabaster varieties are used as a filler in paper, rubber and textile industries, in Keen's cement manufacture, as a surface plaster in agriculture, in the dehydration of oil, as a flux in the smelting of nickel-ores.

The State does not contain any known deposit of gypsum except the solitary occurrence of Selenite in a tank in the Midnapur district as mentioned below :—

Midnapur District :

Chainpat and Dari Ajodhia (22°37′ : 87°49′) : Recently, selenite crystals occurring as nodules (associated with $CaCO_3$ concretions) in the grey coloured clay, were found while excavating a tank in the alluvial country between Chainpat and Dari Ajodhia village in the Midnapur district. The selenite crystals are reported to have been found from a depth of three metres from the surface. On further investigation, distribution of the selenite was found to be rather poor and only 2.72 kg. of selenite per 2.83 cu. m. of clay down to a depth of about 5.5 m. could be recovered (Hunday, 1959).

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12. KYANITE AND SILLIMANITE

Kyanite

Kyanite has a theoretical formula of Al_2O_3 , SiO_2 with 62.93 per cent. of Al_2O_3 and 37.07 per cent. of SiO_2. Hardness varies in different faces from 4 to 7 and sp. gr. is 3.6—3.7. Kyanite usually occurs as blades, or massive lumps. They are usually blue, but owing to impurities greenish and yellowish varieties are also seen.

Uses : At 1200°C, Kyanite is transformed into *mullite* ($3Al_2O_3$, $2SiO_2$) and vitreous silica. In the calcined form, it is used in the manufacture of refractories, bricks, gas burner tips, spark plugs, heater elements and high voltage electric insulators. It is also extensively used in the Ceramic Industry.

Transparent varieties of kyanite find use as semi-precious stones.

Sillimanite

Sillimanite has a theoretical composition of Al_2O_3, SiO_2. Hardness is from 6 to 7 (Moh's scale) and sp. gr. 3.23. Sillimanite is used as

sillimanite bricks in electric industry, in cement, glass, sodium and sulphur industries, iron foundry, coal carbonisation, tar distilling plants, metal smelting and refining furnaces.

Occurrenses

A few kyanite deposites are reported from the State.

Purulia district :

(1) *Salbani* (23°04′ : 86°17′) : Veins of kyanite, 0.61 to over 1 m. in thickness, occur along a narrow belt, about 11.3 m. in length from Salbani to Ichadih (23°04′ : 86°10′) near the Bihar border. But owing to the high percentage of mica present in the rock, it is not suitable for refractory purposes. Khedkar and others (1950) investigated this band of quartz-kyanite which extends for about 48 km. in length upto Tiruldih railway station. The kyanite is found in fine-bladed and massive form containing occasionally blue corundum. They occur as discontinuous veins trending east-west within mica-schists. Detailed prospecting (Khedker and others, 1951) revealed that the reserves of kyanite are of the order of 6,960 tonnes to a depth of three metres from the surface. The production of kyanite from the Purulia district during 1953 was only 20.3 tonnes. Chandra (Krishnan, 1954-55,) thinks that the deposits are too sparsely distributed to be of any economic value.

(2) *Birkhar* (23°34′ ; 86°23′) : Small blades and massive variety of kyanite occur in mica-schists to the north of Birkhar village.

Bankura district :

Mahadevsinan (22°50′ : 86°44′) : A. K. Dey (1937) noted some pieces of kyanite rock in the ridge south of Mahadevsinan in the Bankura district.

Darjeeling district :

(1) A. De (1956) has mapped the kyanite zone, about 1.6 km. wide and 12.9 km. long from north of Mahanadi R. S. (26°53′ : 88°18′) to north of Gayabari (26°50′ : 88°13′) in the metamorphics of the Balasan valley. The kyanite isograd is well marked. The rocks associated with staurolite are coarsely crystalline. Kyanite occurs as colourless to bluish grey crystals containing inclusions of quartz and carbon particles. No workable deposit of kyanite, however, has been reported by him in this zone. But he has observed blue crystals of kyanite

about a centimetre in length from the sillimanite-kyanite gneiss occurring about six kilometres north of *Soureni* (.4,653 ; 26°52′ : 88°12′) and near *Tung* (26°55′ : 88°18′).

(2) Hunday (Krishnan, 1958) has observed that kyanite is sparsely distributed in a narrow belt of metamorphic rocks which runs for about 40 km. from a place having co-ordinates lat. 27°52′ and long. 88°14′, beyond *Lepchajagat* (27°01′ : 88°12′).

Rocks of kyanite and sillimanite zones were also reported from certain sections of Tindharia-Mahanadi-Kurseong-Darjeeling road. Typical succession of sillimanite-kyanite-garnet zones with development of kyanite blades and of sillimanite needles in the corresponding isograds in certain sections of the roads between Darjeeling Ghum Sukhiapokri and Manibhanjan-Tanglu-Sandakphu-Phalut and of Phalut-Gimbik-Jhepi-Phulbazar-Darjeeling road were noted.

(3) Rocks of the kyanite zone have also been found in the metamorphics of the Kalimpong area (Banerjee, T., 1954). The sillimanite zone occurs to the north of *Mahanadi* (26°33′ : 88°18′) and *Tingling* (26°51′ : 88°12′). Mallet (1874) termed the sillimanite zone gneisses as the Darjeeling gneiss. Sillimanite in these rocks occurs as fibrolite after the biotite flakes (Dey, 1956, pp. 52-53). This mineral does not appear to be of economic importance.

Production of sillimanite in the Midnapur district in 1960 is estimated at 16.2 tonnes.

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13. LEAD AND SILVER

General

A few small and scattered deposits of lead-ore have been recorded from the western and northern parts of the State. Several of these deposits were opened up by various companies and syndicates since 1850, but without any success. Dunn (1941, p. 160) thinks that the failure was entirely due to the absence of any deposits of reasonable size.

A serious attempt to open up the lead deposit at Beldi (23°03′ : 86°18′) in the Purulia district was made in 1904-1905 by Messrs Mackinnon Mackenzie & Co. The ore was railed to Howrah and smelted in a small furnace at Shalimar. These contain a small amount of silver. The ores consist mostly of galena, with a little cerussite. The sphalerite and also copper pyrites are sometimes present in these ores. Many of these contain a little antimony.

Occurrences

Purulia district:

(1) *Dhadka* (22°48′ : 86°30′) *area:* Galena was first discovered at Janijhor and Dakia near Dhadka by Ball in 1870. He found that the ore occurs as small lenticular masses, 0.13 to 0.15 m. long, in quartz veins within the mica-schists. Brown hematite is associated with the ore. An analysis of a sample shows 79 per cent. lead, and the silver content found is 119.23 ozs. per ton of lead. The silver content varies from 76.34 ozs. to 119 ozs. per ton of lead (Ball, 1870). Traces of antimony are also found in these ores. Messrs Mackinnon Mackenzie & Co. of Calcutta prospected, during 1904-1905, the deposits at Janijhor (22°48′ : 86°32′), Kushbani (22°48′ : 86°34′), Lata, Lewshai, Panra or Parada (22°49′ : 86°35′), Ghagra (22°49′ : 86°34′), Nanna (22°47′ : 86°35′) and Dakia, all within a radius of 10 km. of the deposit at Dhadka. These are mere pockets, superficial and discontinuous (Dunn, 1941, p. 161). Recently, the Geological Survey of India have carried out investigation of these copper-lead-zinc deposits. Geochemical prospecting shows moderate lead anomalies (75 to 500 p.p.m.) at 400 to 600 m. N.N.W. of Janijhor, at Mirgichani, Lewshai and Satraguda. Copper anomalies are rare. The quartz veins traversing the country rock contain copious amounts of limonite. Murthy and Shinde country rocks schists, phyllites, epidiorites, and gneisses of Archaean age (Roy, 1964).

(2) *Beldi* (23°03′ : 86°18′) : Galena was found associated with low grade metamorphites near Beldi in Purulia district. The low grade metamorphites are phyllites and schists showing brecciation, concomitant recrystallisation and large scale silicification. Galena, associated with quartz, occurs in veins part of which had been worked out by Messrs Mackinnon Mackenzie & Co. during 1904-05. The company extracted about 272 tonnes of ore which yielded 92 tonnes of lead, 134 g. of silver and 86 grains of gold (Krishnan, 1954-55). The associated minerals are cerussite, anglesite, malachite, azurite and a little chalcopyrite.

(3) *Biramdih* (23°03′ : 86°12′): D. K. Chandra (Krishnan, 1954-55) reported occasional pockets of galena in a quartz vein south of Biramdih. It is sporadically distributed and is associated with some chalcopyrite.

(4) *Bhagaband* (23°11′ : 86°44′) : An occurrence of galena associated with a few columnar crystals of corundum in an epidote bearing pink aplitic gneiss has been recorded by A. Hunday (1951) at a depth of 0.61 to 1 m. from the surface in a small tank about 800 m. east of Bhagaband. Several prospecting pits were dug here in an east-west direction by private parties during 1950, and a total quantity of 18 Kg. of ore is said to have been extracted by them from a pit measuring 14.3 m. × 2.9 m. × 1.22 m. The lead-ore was noted in lumps distributed in a 30 cm. wide zone. One small vein trending north-south and containing galena was exposed during excavations. Green malachite staining is also noticed in the adjoining granitic rocks.

(5) *Malthol* (23°26′ : 86°26′) : A little galena has been detected in barytes from Malthol (Dunn, 1941).

Bankura district :

(1) *Kama* (22°53′ : 86°44′) and *Banka Kacha* (22°54′ : 86°43′) : Minor occurrences of galena have been recorded from Kama and Banka Kacha in Bankura district. These occurrences are in quartz veins in pelitic rocks (Dunn and Dey, 1937). One vein with sulphide minerals is exposed near Dungrikuti (22°53′ : 86°43′) (Chakravarty *et al* 1960, p. 26).

(2) *Gopinathpur* (22°56′30″ : 86°48′30″) : Galena occurs in quartz veins within pelitic rocks just west of Gopinathpur village. The veins run a few metres beneath the surface and do not crop out. They trend parallel to the strike of the country rock. The lode is about one metre wide and appears to persist to considerable depths (Sirkar, 1960).

Galena occurs as massive crystalline aggregate. The most common associated mineral is quartz. The average sp. gr. of a picked sample is 7.31. One picked sample shows on analysis 78.75% lead, the insoluble matter, iron and copper percentages being negligible.

Ore-microscopic studies (Sirkar, 1960) reveal the presence of small quantities of pyrite, chalcopyrite, arsenopyrite, chalcocite and covellite along with galena.

Sirkar suggests a hydrothermal origin for the veins, caused by granitic intrusions in close proximity,—faults and shear zones being the structural controls for the deposition of the lodes.

(3) *Burisal* (22°47′ : 86°42′) : Sulphide veins have been reported from Burisal (Chakravarty *et.al.*, 1960), (4) *Haramgara* (22°42′ : 86°43′) : Sulphide veins have been reported from Haramgara (*op. cit*, p. 26).

Midnapur district : Gohalberia (22°39′ : 86°43′) : Galena is found in the dumps around some old excavations near the soapstone quarries west of Gohalberia in the Midnapur district.

Darjeeling and Jalpaiguri districts : Argentiferous galena, cerussite, sphalerite and limonite are reported to occur as small pockets in the grey dolomite bands in the Buxa Duara area of the Jalpaiguri district. It is stated that from a tonne of average lead-zinc ore, about 143 gm. of silver can be obtained.

Occurrences of lead in other places of the Darjeeling district, specially in the Sakkam river area, have also been reported.

The lead and silver resources of the country have not been fully assessed. Khedkar (1950) is of the opinion that new ventures in prospecting and opening, some of the known deposits of lead may become profitable under a modern scientific set up. This has been borne out by the fact that the lead from the Zawar mines in Rajasthan is now being smelted at Tundoo near Katrasgarh in Bihar, and the zinc concentrates are sent to Japan, for smelting. At the present stage, therefore, it seems necessary to investigate in details at least some of the known occurrences of lead and silver, and arrive at definite conclusions regarding their possibilities.

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14. MAGNESIUM ORES

There is no known deposit of magnesite ($MgCO_3$), the principal ore of magnesia, in the State.

Magnesite is principally used in the manufacture of refractory bricks for furnace linings. Magnesium salts are used in manufacture of sorel cement, in rubber industry (where MgO should be 40 to 43.5 per cent. by weight as per I.S.S. specification), in pharmaceuticals etc.

Magnesium metal is used in photography, fire works, incendiary bombs, paints, for signalling, in the manufacture of light alloys, and in the manufacture of air-planes and automobile bodies.

Although magnesium is an important constituent of many rocks and minerals, it is normally extracted from sea water. The bittern for the manufacture of epsom salts at the Salt Works in the Calcutta Salt Agency (now defunct) contained 4.8 per cent. magnesium chloride. It is obtained as a by-product during the manufacture of common salt from sea water.

It will be of great interest to note that the extraction of magnesium metal from dolomite by silico-thermal reduction process on a laboratory scale has been successfully done by the National Metallurgical Laboratory. Now the production has been extended to pilot-plant scale with a rated production of 11.3 kg. of magnesium from dolomite per day.

The large deposit of dolomite at Buxa Duars of the Jalpaiguri district should proveas a potential source for the manufacture of magnesium, once the problem of cheap power is solved. The production of magnesium metal from the conventional sea water also needs proper attention.

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15. MOLYBDENITE

Molybdenite, the chemical composition of which is molybdenum disulphide (MoS_2) with sulphur 40 per cent. and Mo 60 per cent. (hardness varies from 1 to 1·5 and sp. gr. from 4.7 to 4.8), is an important ore of molybdenum.

Molybdenite is principally used in the steel industry as alloy with iron and calcium (1 to 1.5 per cent.). This imparts strength, elasticity, resistance to shock and fatigue. It is also used in cast irons, high speed self-tempering machine tools, in the manufacture of incandescent lamps, in wireless valves, and in the manufacture of electrodes. Molybdenum compounds are used in chemical and ceramic industries. It may be mentioned here that rhenium, the rare element, is mostly found in molybdenum-ores.

Purulia district :—Molybdenite is reported to occur in the metamorphic rocks of the Purulia district. These occurrences are only of mineralogical interest.

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16. PLATINUM

Platinum is one of the noble metals having hardness 4 to 4.5 and sp. gr. 14 to 19 (native). Platinum is greatly valued in jewellery and other decorative purposes. Besides these, platinum is used for the manufacture of laboratory ware. Platinum, by itself, or in combination with other elements of the group, may be used as a catalytic agent, for the conversion of SO_2 to SO_3, in the manufacture of sulphuric acid, in the production of high octave petrol and other petroleum products, in electro-chemical industry, in the preparation of hydrogen peroxide, in electro-plating, glass wool industry, rayon, artificial silk, sparking plugs, telephones, resistance thermometres, thermocouples etc.

Dhadka (22°48′ : 85°30′) *area, Purulia district* : Mallet (1882) detected minute grains of platinum in a sample of stream gold from the Gurnam river near Dhadka. The largest scale weighed about 0·005 grammes. Similar scales were found in the gold concentrates from other rivers in the same region. E.O. Murray (Dunn, 1941) also found silvery grains of platinum while panning for gold along the Gurnam river. But Dunn (1941) remarked that further survey did not confirm the presence of platinum along this stream.

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17. PYRITES AND SULPHUR

In the absence of any commercial deposit of native sulphur in India, pyrite (FeS_2) is regarded as one of the important sources of sulphur which is a strategic raw material for the country. Sulphur is required in many industries. Its most important uses are in the manufacture of sulphuric acid, chemicals, in tin plating, fertilisers, paper, explosives, dyes and coal-tar products, rubber, paint and

varnish, food products and acid-proof cements. In fact, the amount of consumption of sulphur in any country is an index of its advancement in industrialisation.

There is no known good deposit of pyrites in West Bengal, excepting a few small and sporadic occurrences mentioned below, which are only of an academic interest.

Occurrences

Burdwan district :—The coal seams of the Raniganj coalfield contain small amount of pyrite (iron pyrite). These can not be regarded as a source of pyrite, as the amount is very small and the deposits are dispersed in the coal seams in a very irregular manner. Small quantities may be recovered and concentrated from the coal washing plants (Altekar and Vasudeva, 1960).

Bankura district :—The coal seams and the Archaean rocks in the Bankura district contain small specks of pyrite and chalcopyrite.

Jalpaiguri district :—Thin disseminations of pyrite in slates and quartzites of Daling series and in the dolomite rocks of the Buxa Duars (26°46′ : 89°37′) area in the Jalpaiguri district have been noted.

Darjeeling district :—Occurrences of chalcopyrite have been noted from many places in the district (See 'Chapter on Copper').

Occurrence of arsenical pyrites are described under Arsenic.

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18. TITANIUM ORES

The minerals ilmenite (FeO, TiO_2) and rutile (TiO_2) and titaniferous magnetite are the main sources of titanium. These are quite common in many rocks, but workable deposits are few. The most important source of titanium in India, and also in the world are the beach sands of Travancore. Other occurrences include Ratnagiri in Bombay, the southern districts of Madras, Visakhapatnam in Andhra Pradesh and

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19. URANIUM ORES (Allanite)

Purulia, Bankura and Midnapur districts : The uranium bearing mineral, allanite, occurs as an accessory mineral in the Kuilapal granites gneiss at the tri-junction of Purulia, Bankura and Midnapur districts (Chakravarty, 1957). In the Bankura district, it occurs mainly in Madhabpur and Tilaboni areas. Allanite is also found in the surrounding mica-schists and in the calc-granulite inclusions within the granite gneiss. Percentage of allanite diminishes from the granite gneiss boundary outwards. This variation is more pronounced in the calc-granulites. These are often metamict and isotropic with N-1.65, and found as cores in epidote grains. It is also found occasionally in pegmatites occurring within the Kuilapal granite gneiss. A preliminary examination of the mineral in β-Ray counter indicates that the mineral is radioactive with a strong γ-ray background. Allanite also occurs in association with barytes at Malthol (23°26′ : 86°26′) in a five kilometre long belt through Belna and Raghudih (23°26′ : 86°27′), where the vein is about 15 m. long.

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the Orissa coast deposits. The beach sands of Midnapur in West Bengal have not been studied in detail and their heavy mineral contents are not known. The examination of the Tertiary pebble beds (littoral shelf deposits) of Bengal, Bihar and Orissa has indicated the presence of such heavy minerals as monazite, xenotime, ilmenite, zircon, magnetite and gold (Khedker, 1954). Ilmenite and rutile are found as small veins and aggregates in the pegmatites and as veins associated with quartz veins traversing gneissic country or as loose grains. Titanium is also available from titaniferous and vanadiferous magnetite.

Uses and Properties

Titanium oxide (titania, TiO_2) has found a wide use in brush and spray lacquers. It is the most valuable filler and pigment because of its covering power, perfect whiteness and almost complete inertness. It is called the wonder metal in modern industries. It is used as a pigment in the plastic industry in bakelite and similar synthetic phenol and cresol products and in celluloid or pyroxylin plastics. Titania is also used as a pigment in the manufacture of linoleum, coated textiles, rubber, wall papers, printing ink, glass, ceramic glaze and enamelware. Titanates are also finding increasing use in electrical ceramics. Titanium in chromo-nickel steel reduces intergranular corrosion, and is used in aero-engines. The tetrachloride is used for smoke screens, and the bichloride and sulphate in the dye industry.

Occurrences

Purulia district

(1) *Manbazar* (23°03′ : 86°40′) : Ball (1881, p. 107) has mentioned the occurrence of massive ilmenite at the foot of the hills to the W.N.W. of Manbazar.

(2) *Supur* (23°01′ : 86°52′) : Ilmenite occurs in large masses in quartz veins near Supur. These ilmenite bearing quartz veins extend to the adjoining Bankura district.

(3) *Turga nala and near Baorajora* (23°12′ : 86°05′) : Small occurrences of ilmenite are recorded in pegmatites exposed along the Turga *nala* and near Baroajora (Krishnan, 1954-55).

(4) *Gaurangdih* (23°26′ : 86°46′) : Ilmenite and rutile have been found in a number of localities within about 10 km. radius of Gaurangdih railway station. These occur in pegmatites and quartz

veins traversing the biotite-plagioclase (andesine) gneiss and the associated hypersthene meta-gabbros and less frequently the sillimanite-mica schists of the area. They form sometimes five per cent. of the volume of the host rock (Mahadevan, 1960, p. 259). P. R. Sengupta (1960, p. 269) is of the opinion that these ilmenites have crystallised from an interstitial liquid rich in titania, after the separation of the major bulk of rutile.

(5) *Salbani* (23°04′ : 86°17′) : Well developed crystals of rutile, sometimes 1.3 cm. in thickness, are found scattered on the ground close to the kyanite deposits near Salbani (Warth, 1892 ; *cited by* La Touche, 1918).

Occurrences of rutile in pegmatites have also been reported from the following localities :—

(6) *Bastadih* (23°24′ : 86°46′).
(7) *Dhopahari* (23°26′ : 86°45′).
(8) *Dejori* (23°23′ : 86°48′).
(9) *Jhalda* (23°22′ : 86°00′) : Numerous small crystals of magnetic titaniferous iron-ores including ilmenite and rutile occur in the porphyritic grey Jhalda gneiss and also within pegmatites traversing the gneiss. The crystals range upto a diameter of 2.6 cm. and are also found within gneisses near Hesla, Baghmundi, south of Jhalda, and at Bansa Pahar near Jhalda (Guha Sarkar, *et. al.*, 1959).

Bankura district : Ilmenite occurs in small to large lumps in quartz veins near the tri-junction of Bankura, Midnapur and Purulia districts, and is also occasionally noticed in the sands of *nalas* and rivers.

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